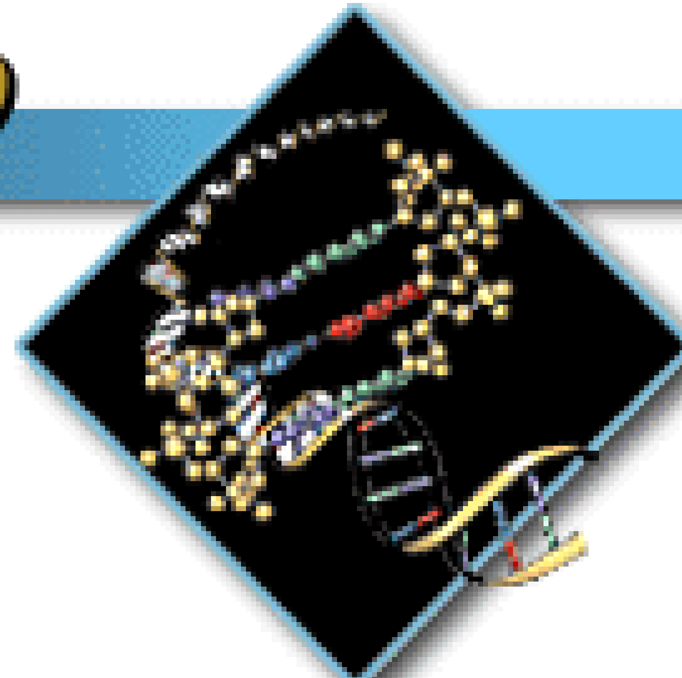
CHAPTER 2

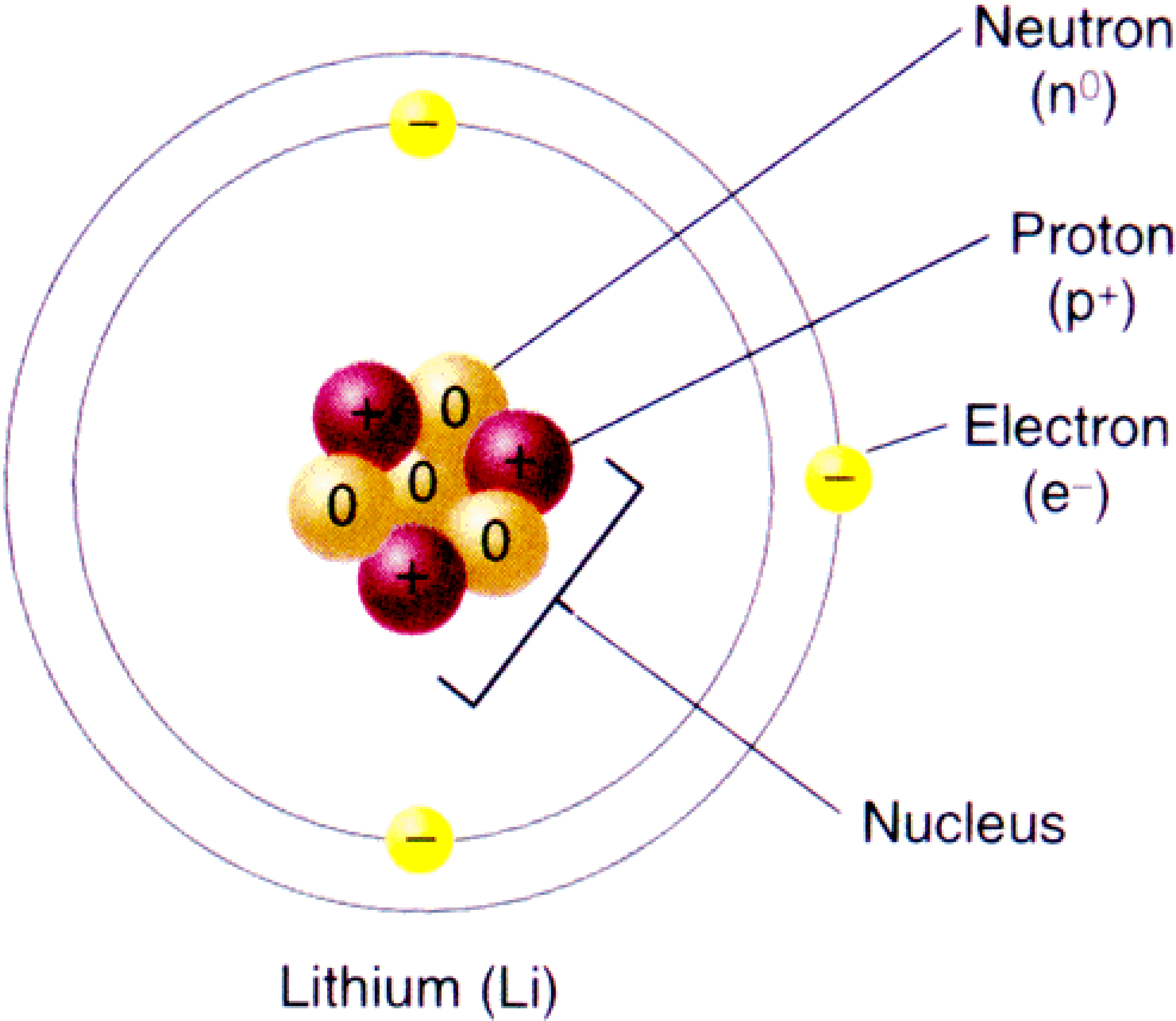
The Chemical Level of Organization



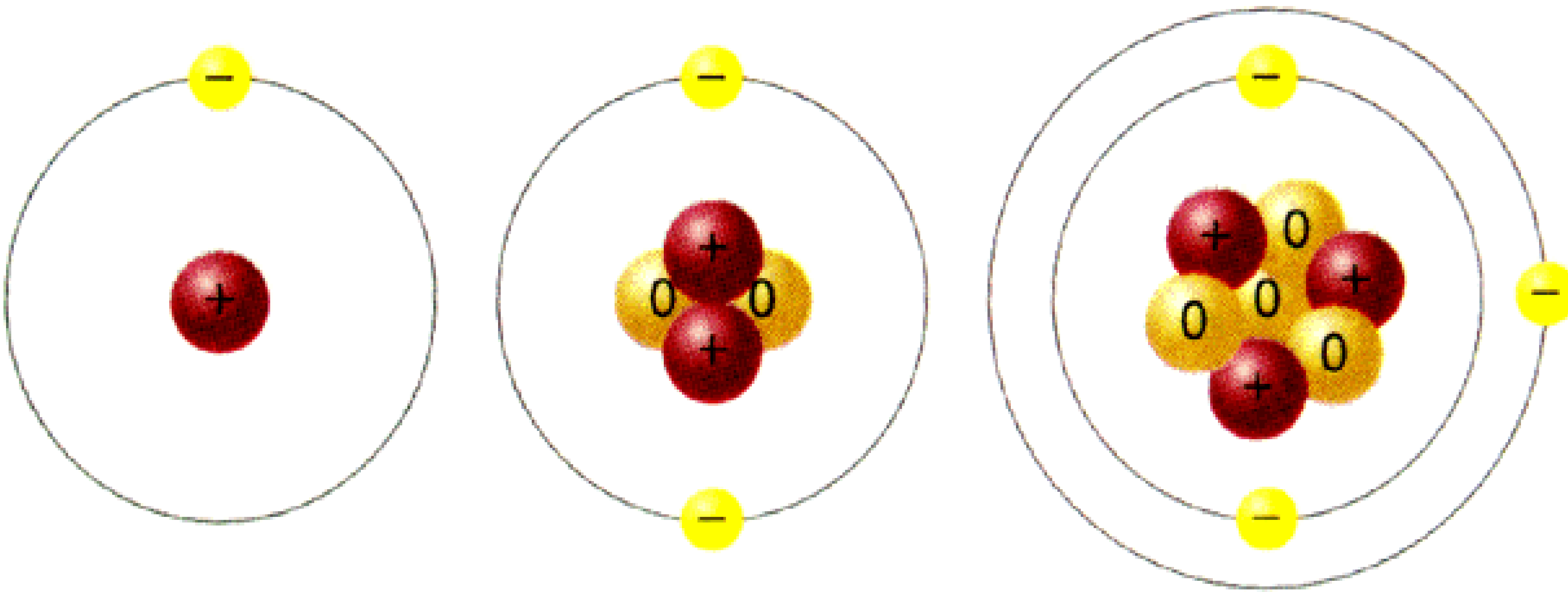
BASIC CHEMISTRY

Anatomy & Physiology 1

Atom of Lithium.

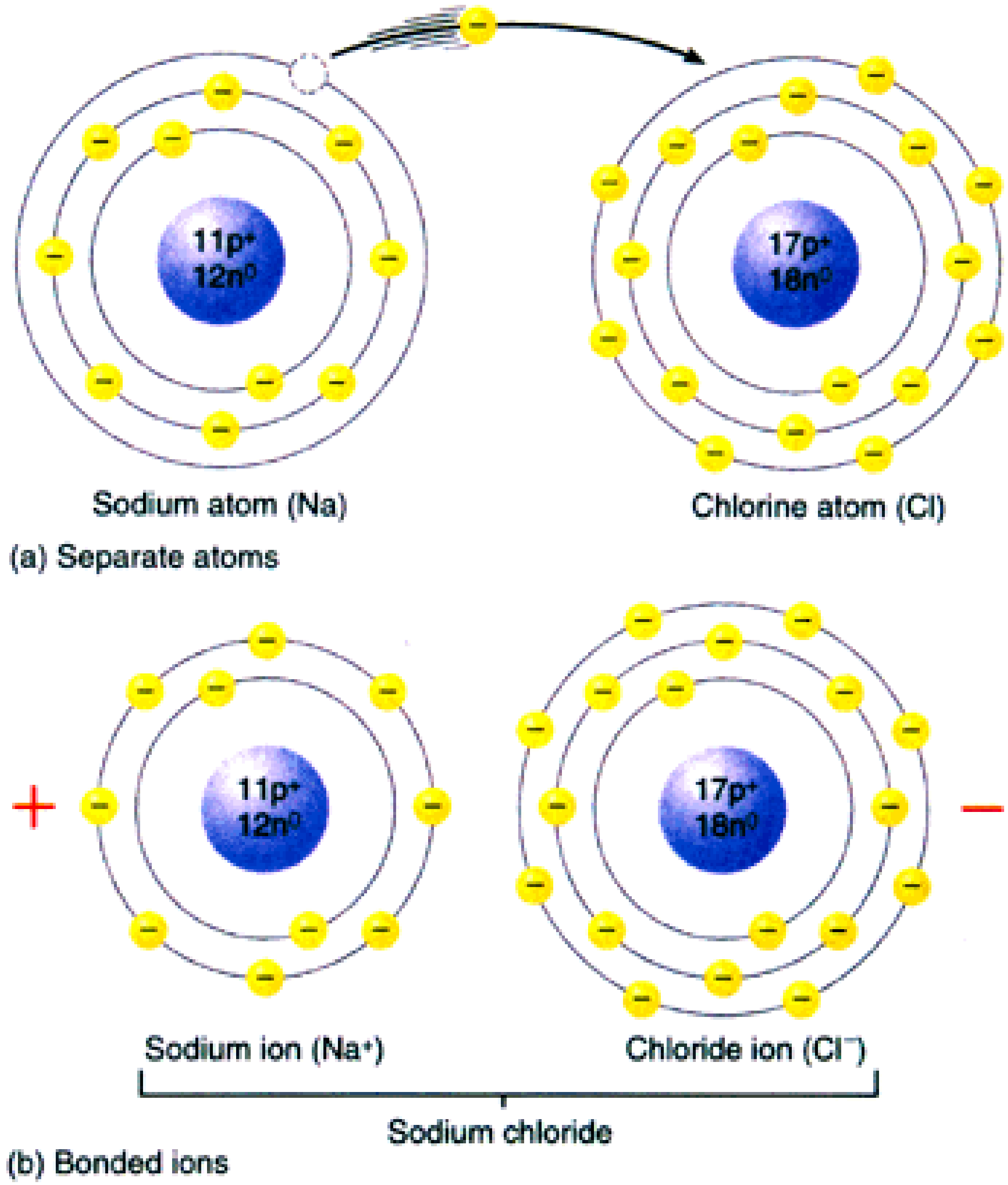


Hydrogen Atom.



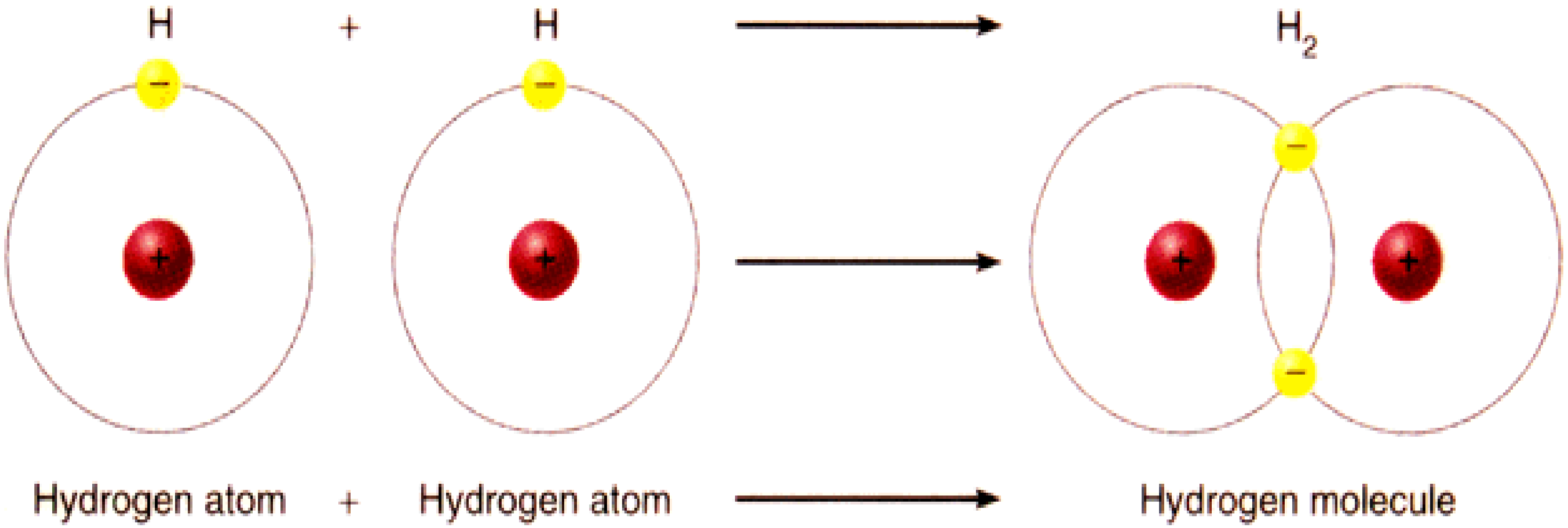
Hydrogen (H) Helium (He) Lithium (Li)

Sodium Atom.

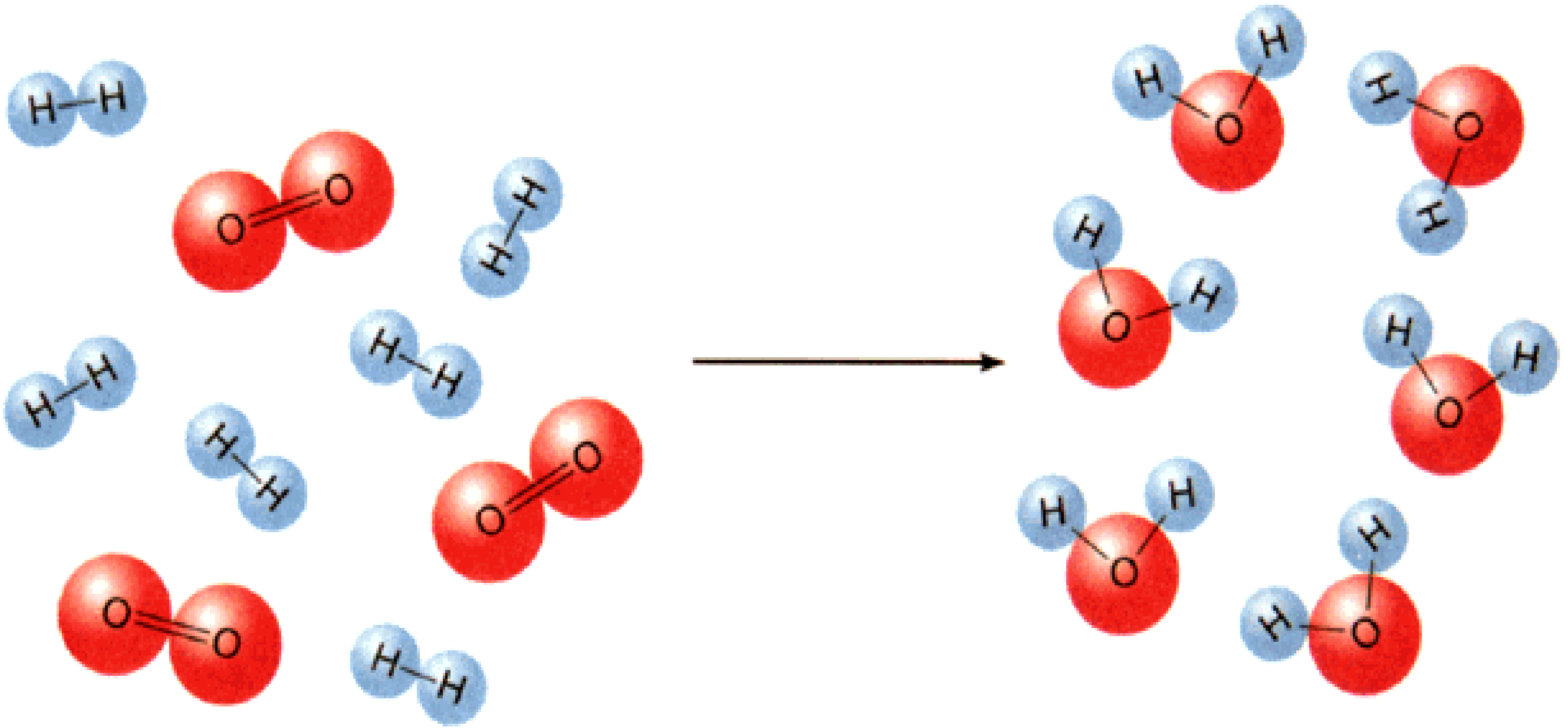


11p+
12n0
17p+
18n0
Sodium atom (Na)
Chlorine atom (Cl)
(a) Separate atoms
+
11p+
12n0
17p+
18n0
−
Sodium ion (Na+)
Chloride ion (Cl−)
Sodium chloride
(b) Bonded ions

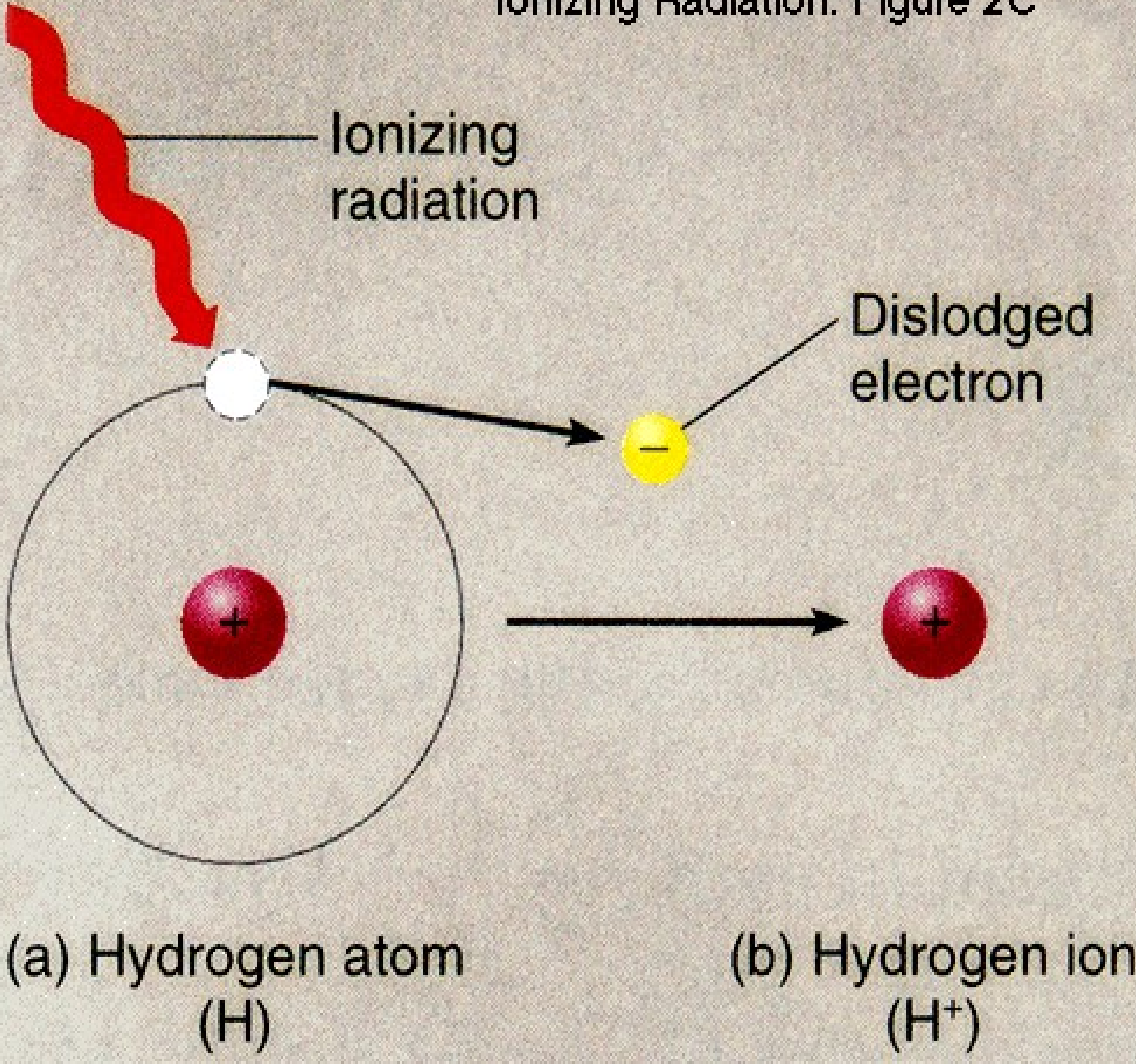
Hydrogen Molecule.



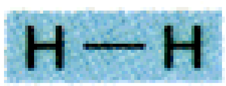
Water Molecules.



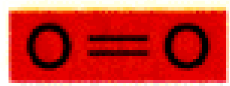
Ionizing Radiation. Figure 2C



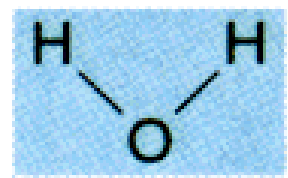
Double Covalent Bonds.



H_2



O_2

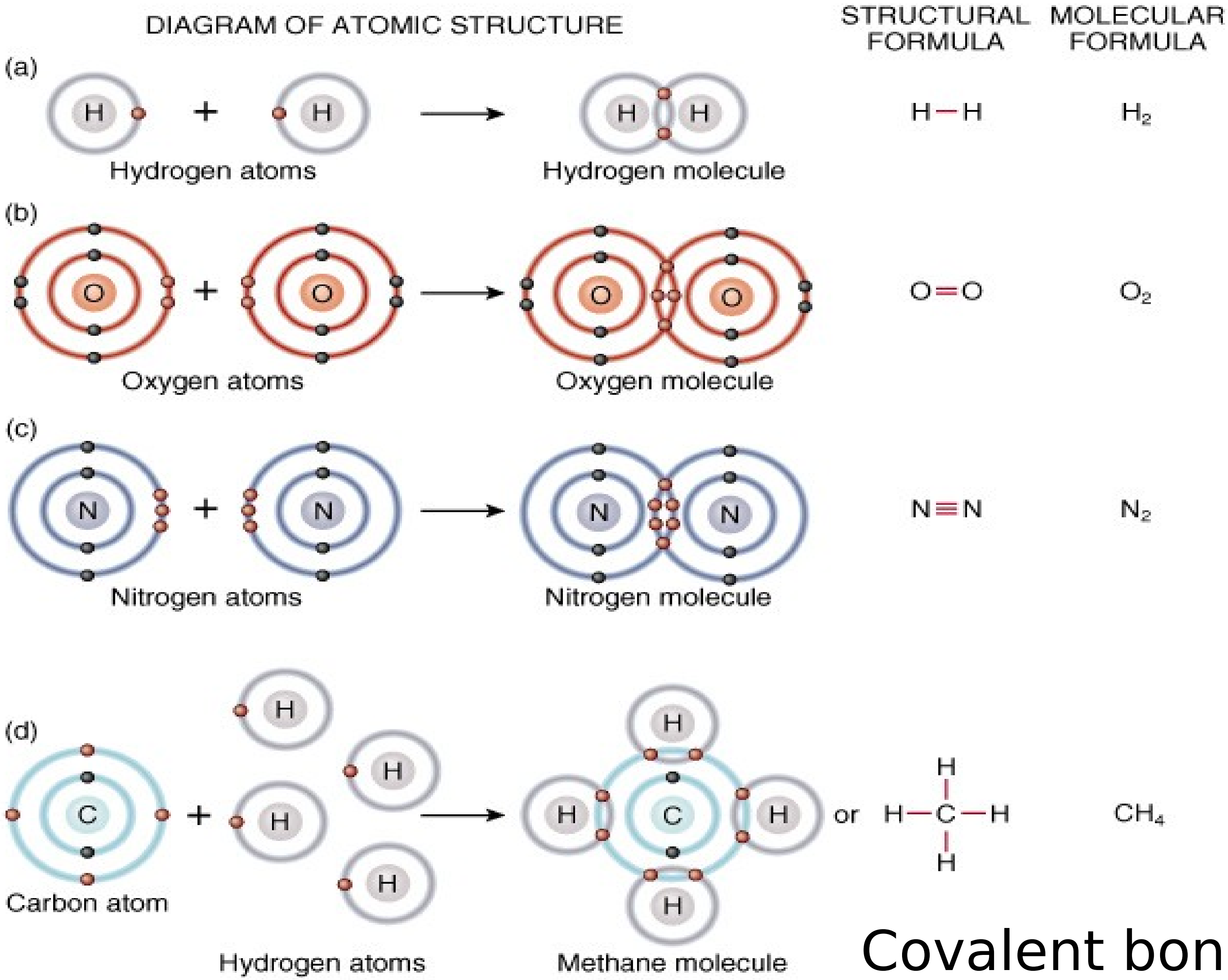


H_2O

CO_2

Covalent Bonds

- Covalent bonds are formed by the atoms of molecules sharing one, two, or three pairs of their valence electrons.
  - Covalent bonds are the most common chemical bonds in the body.
  - Single, double, or triple covalent bonds are formed by sharing one, two, or three pairs of electrons, respectively (Fig. 2.5).
- Covalent bonds may be nonpolar or polar.

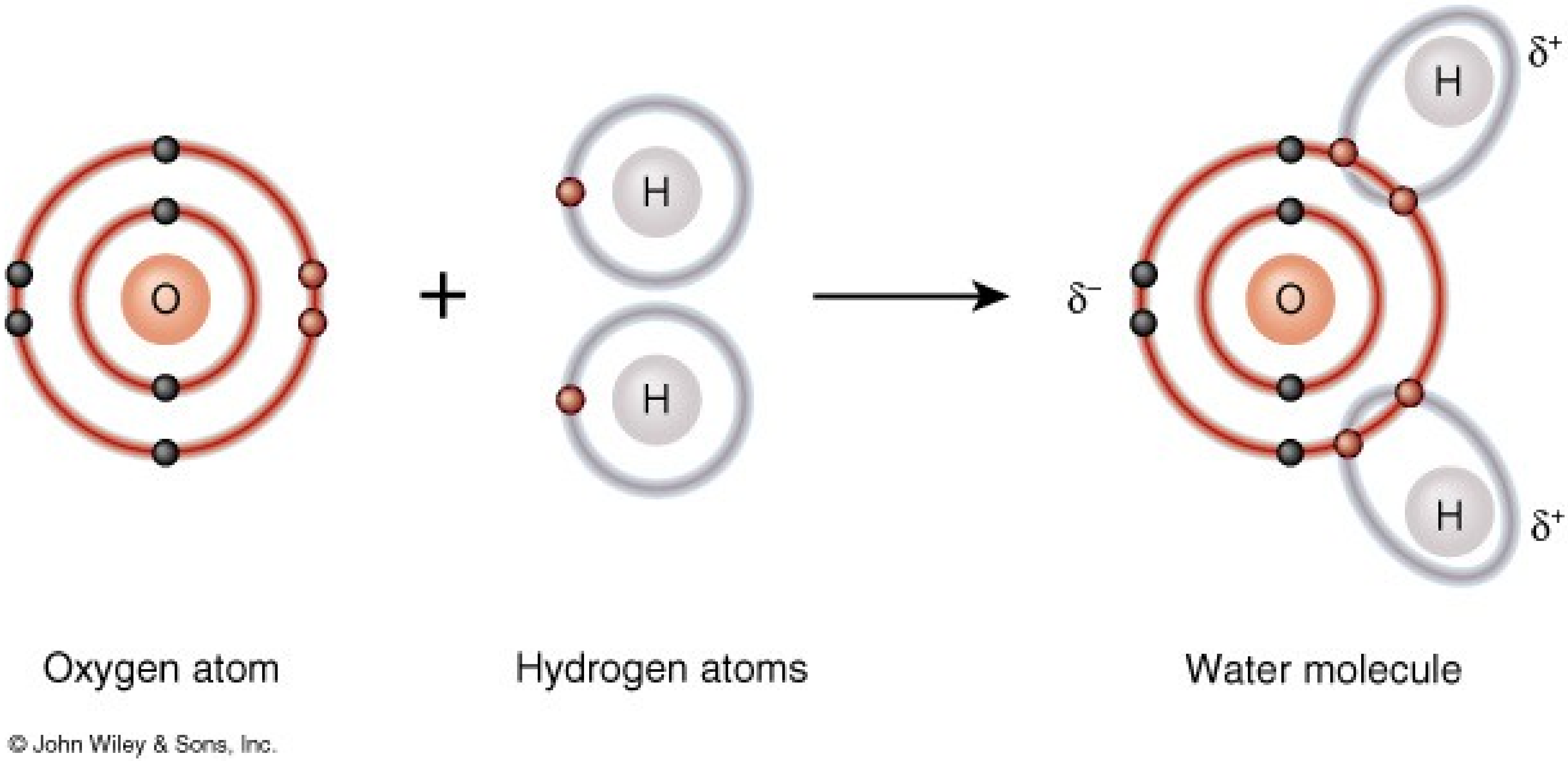


Covalent bonds

Covalent Bonds

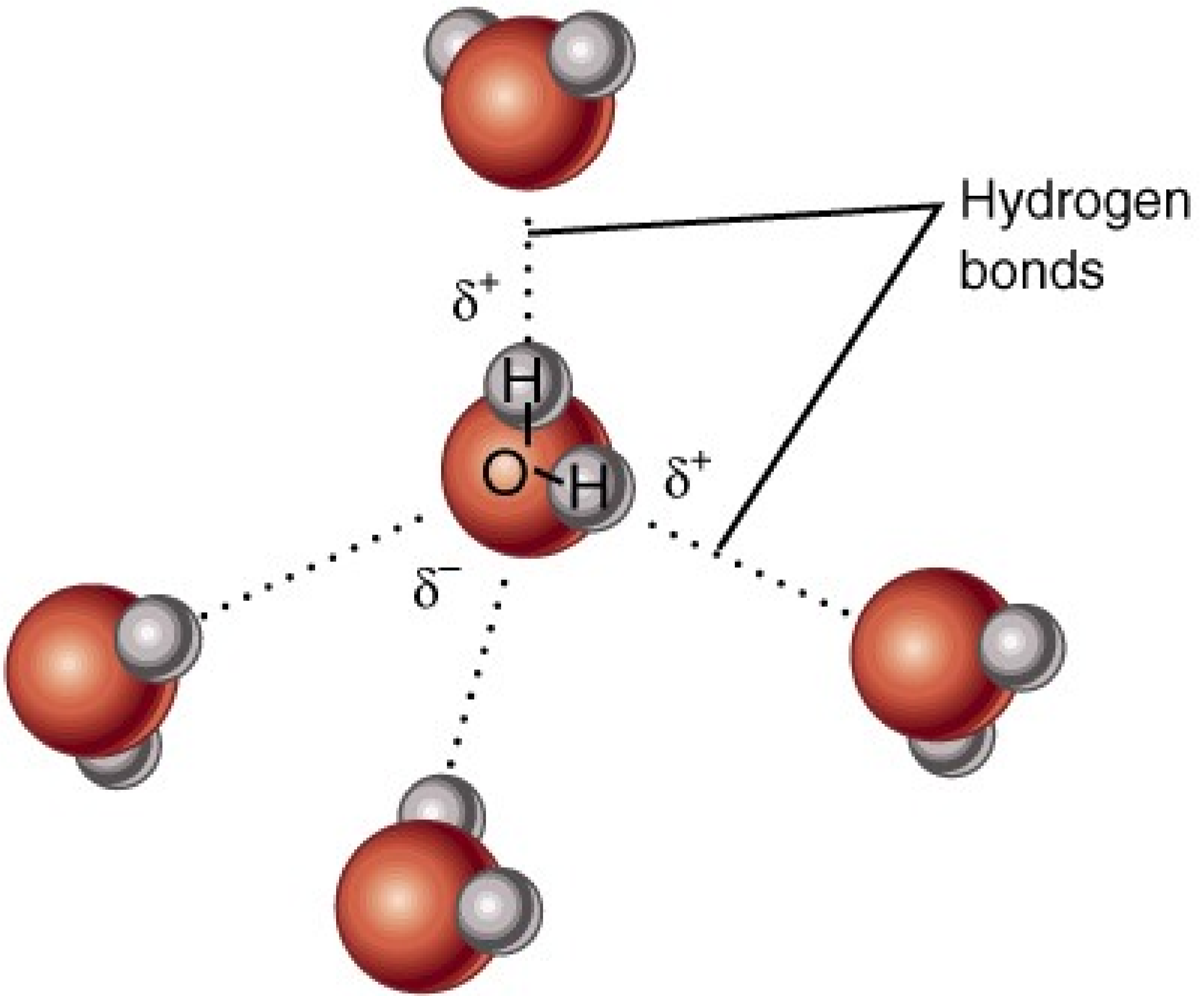
- In a nonpolar covalent bond, atoms share the electrons equally; one atom does not attract the shared electrons more strongly than the other atom (Fig 2.5).
- In a polar covalent bond, the sharing of electrons between atoms is unequal; one atom attracts the shared electrons more strongly than the other (Fig. 2.6).

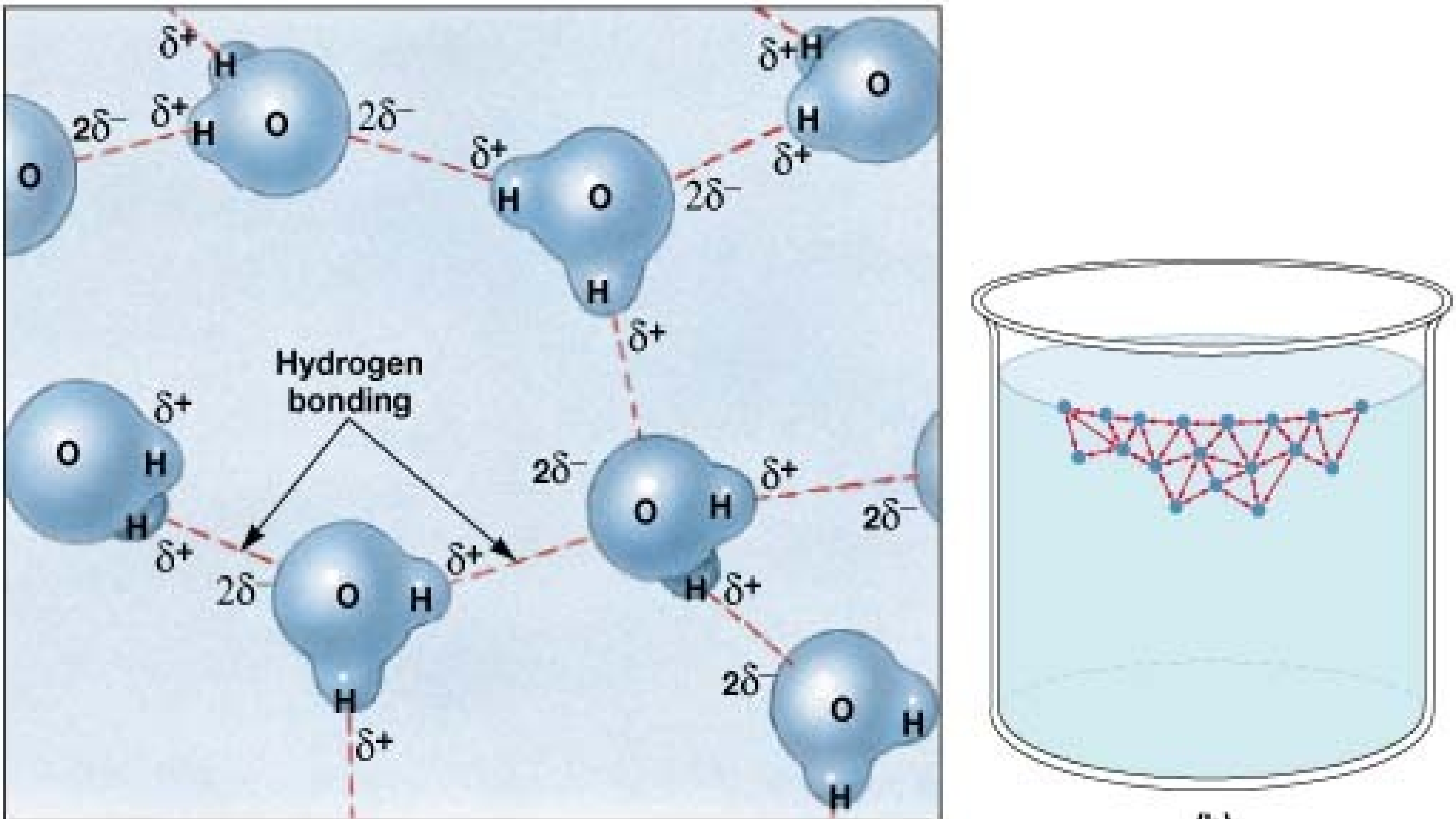
Polar covalent bond



Hydrogen Bonds

- In a *hydrogen bond*, two other atoms (usually oxygen or nitrogen) associate with a hydrogen atom (Fig. 2.7).
  - Hydrogen bonds are weak and cannot bind atoms into molecules. They serve as links between molecules. They provide strength and stability and help determine the three-dimensional shape of large molecules.


Hydrogen bonds
δ+
H
O
H
δ+
δ−

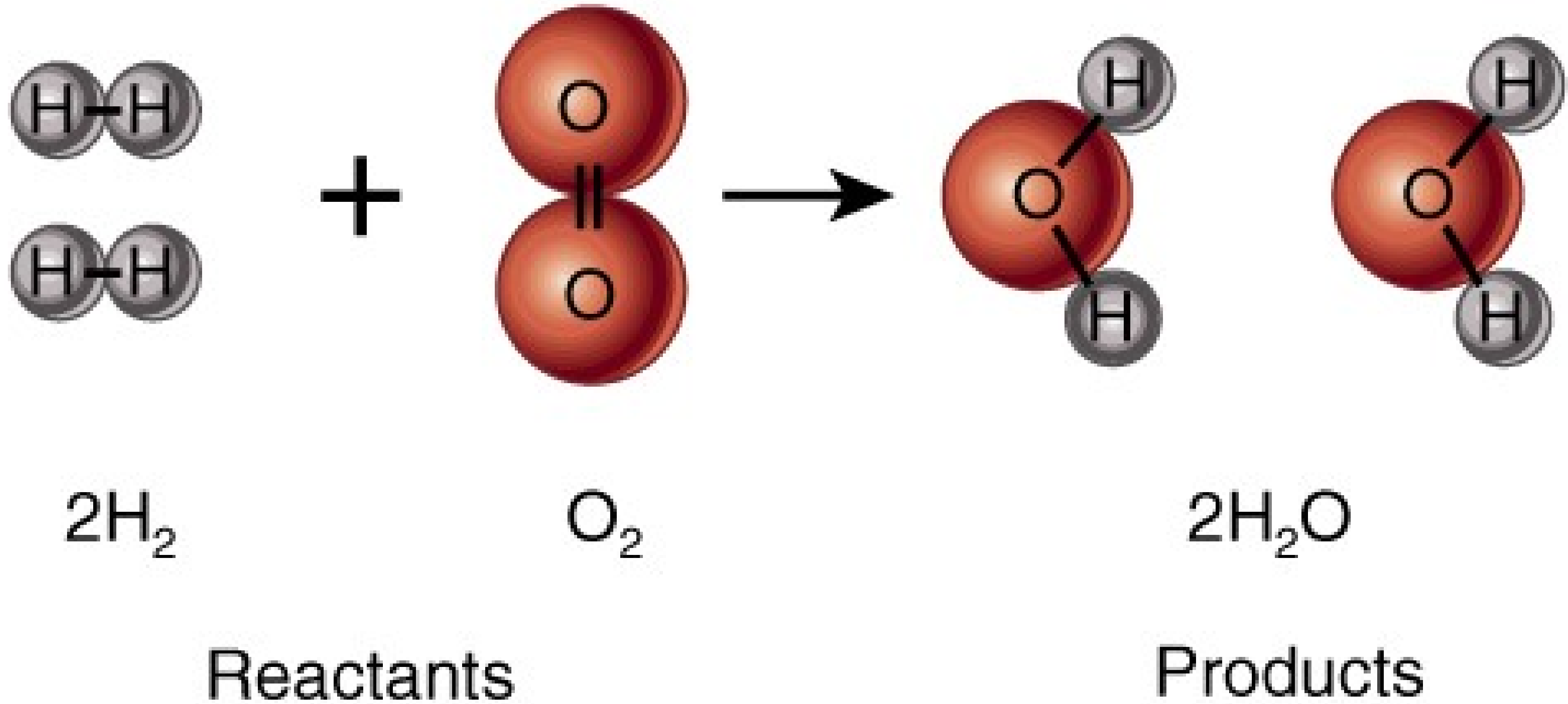


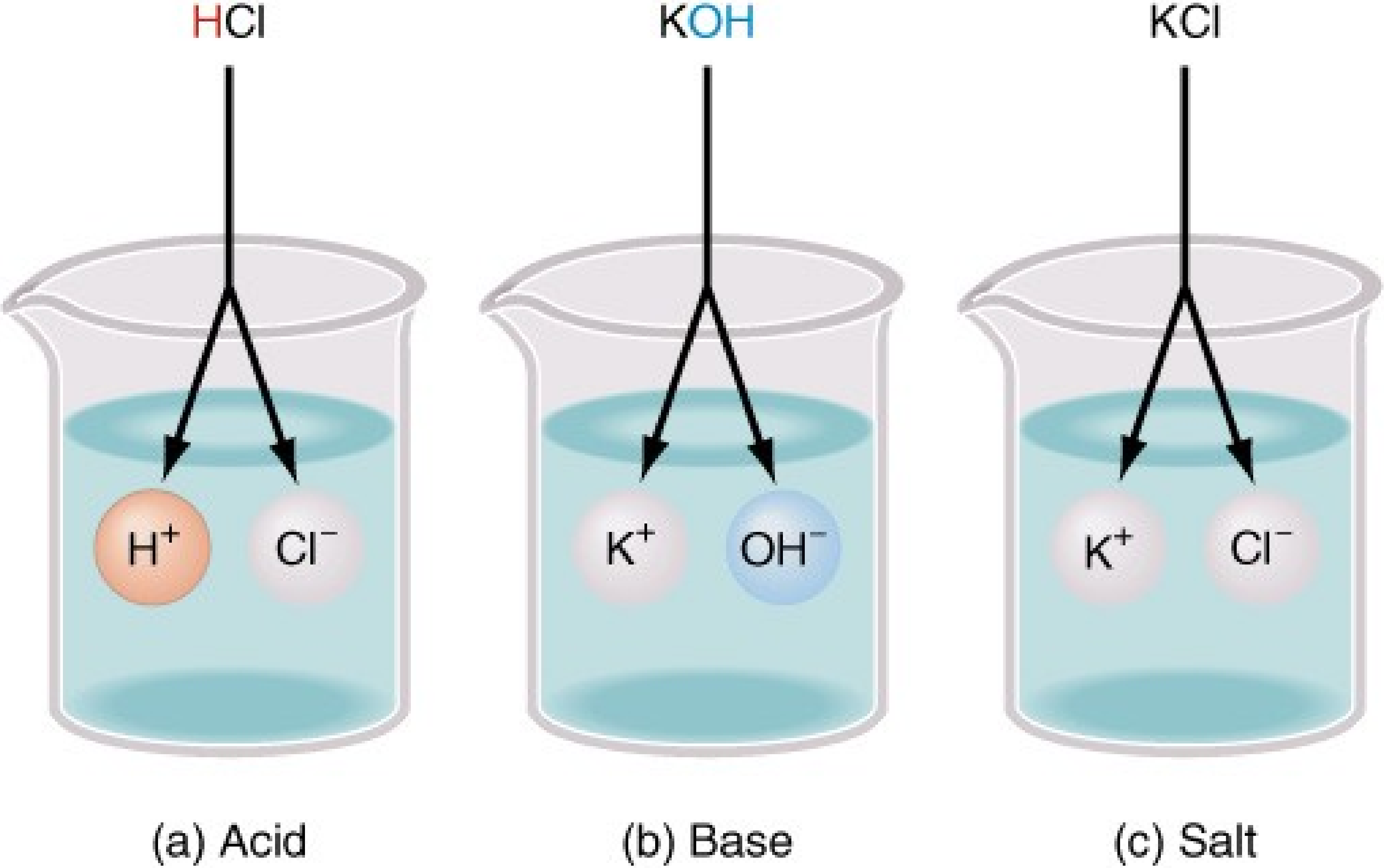
(a) (b)

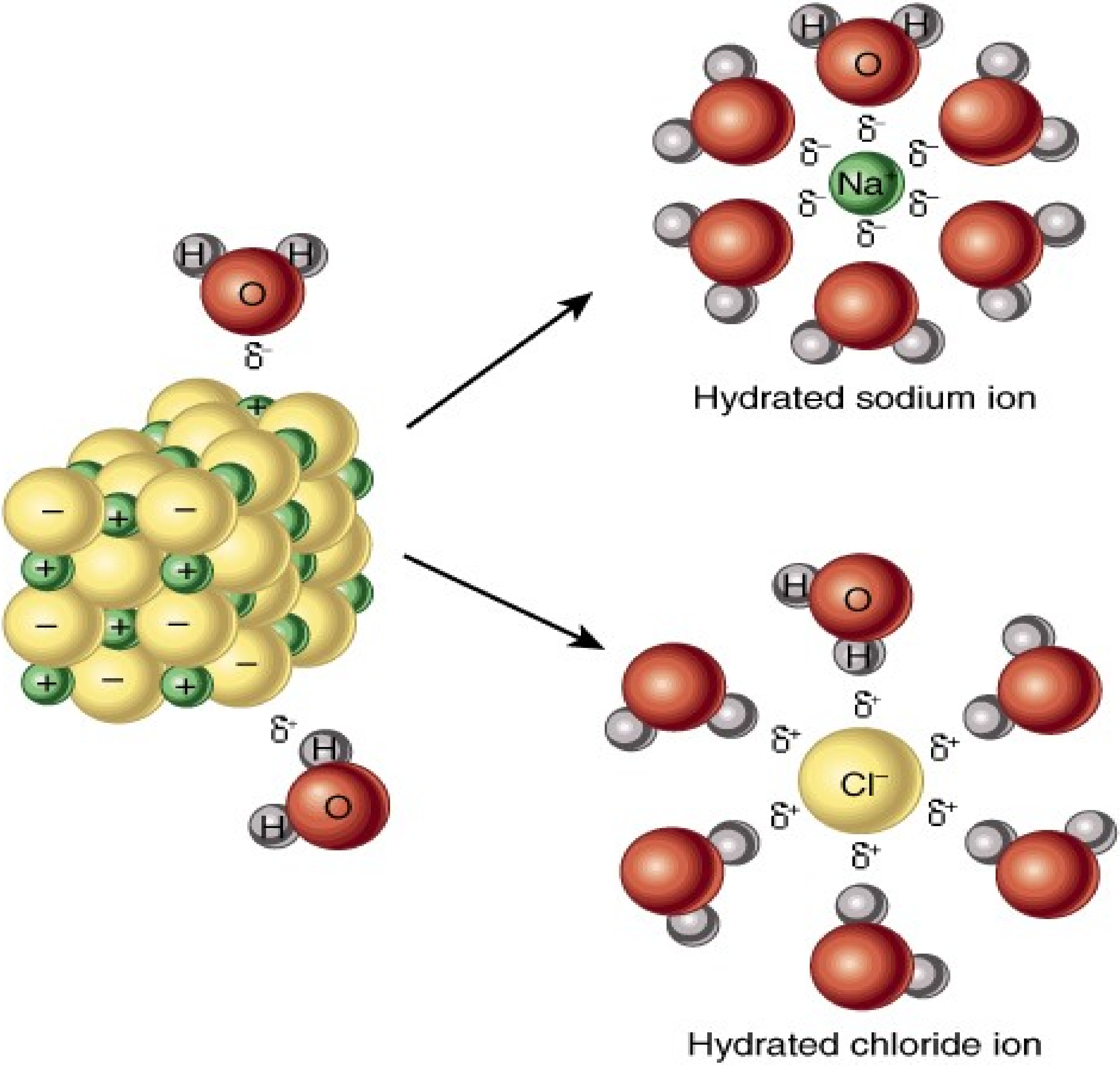
• ***FIGURE 2-6*** **Hydrogen Bonds.** **(a)** The hydrogen atoms of a water molecule have a slight positive charge, and the oxygen atom has a slight negative charge (see Figure 2-5). Attraction between a hydrogen atom of one water molecule and the oxygen atom of another is a hydrogen bond (indicated by dashed lines). **(b)** Hydrogen bonding between water molecules at a free surface restricts evaporation and creates surface tension.

Chemical Reaction

- A *chemical reaction* occurs when new bonds are formed or old bonds break between atoms (Fig. 2.8).
  - The starting substances of a chemical reaction are known as *reactants*.
  - The ending substances of a chemical reaction are the *products*.
  - In a chemical reaction, the total mass of the reactants equals the total mass of the products (the law of conservation of mass).


2H2
O2
2H2O
Reactants
Products


HCl
KOH
KCl
H+
Cl−
K+
OH−
K+
Cl−
(a) Acid
(b) Base
(c) Salt


H
O
H
δ⁻
δ⁺
H
O
H
+
−
Na⁺
Hydrated sodium ion
Cl⁻
Hydrated chloride ion

Ions, Molecules, Free Radicals, and Compounds

- If an atom either gives up or gains electrons, it becomes an *ion* - an atom that has a positive or negative charge due to having unequal numbers of protons and electrons.
- When two or more atoms share electrons, the resulting combination is called a *molecule* (Fig. 2.3a)

Ions, Molecules, Free Radicals, and Compounds

- A *free radical* is an electrically charged atom or group of atoms with an unpaired electron in its outermost shell (Fig 2.3b). Free radicals become stable by either giving up their unpaired electron or by taking on an electron from another molecule.
- Antioxidants are substances that inactivate oxygen-derived free radicals.

Ions, Molecules, Free Radicals, and Compounds

- A *compound* is a substance that can be broken down into two or more different elements by ordinary chemical means.
- Free radicals are linked to numerous disorders and diseases!

Ionic Bonds

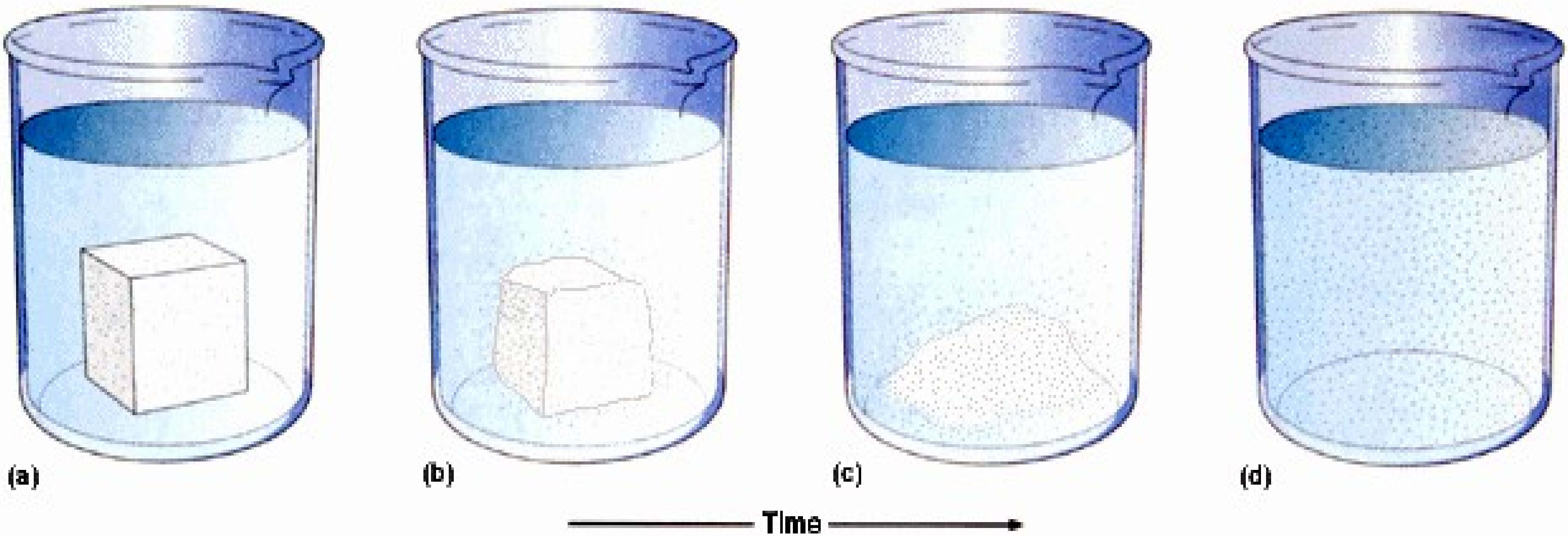
- When an atom loses or gains a valence electron, ions are formed (Fig. 2.4). Positively and negatively charged ions are attracted to one another. When this force of attraction holds ions having opposite charges together, an *ionic bond* results.
  - *Cations* are positively charged ions that have given up one or more electrons (they are electron donors).

Ionic Bonds

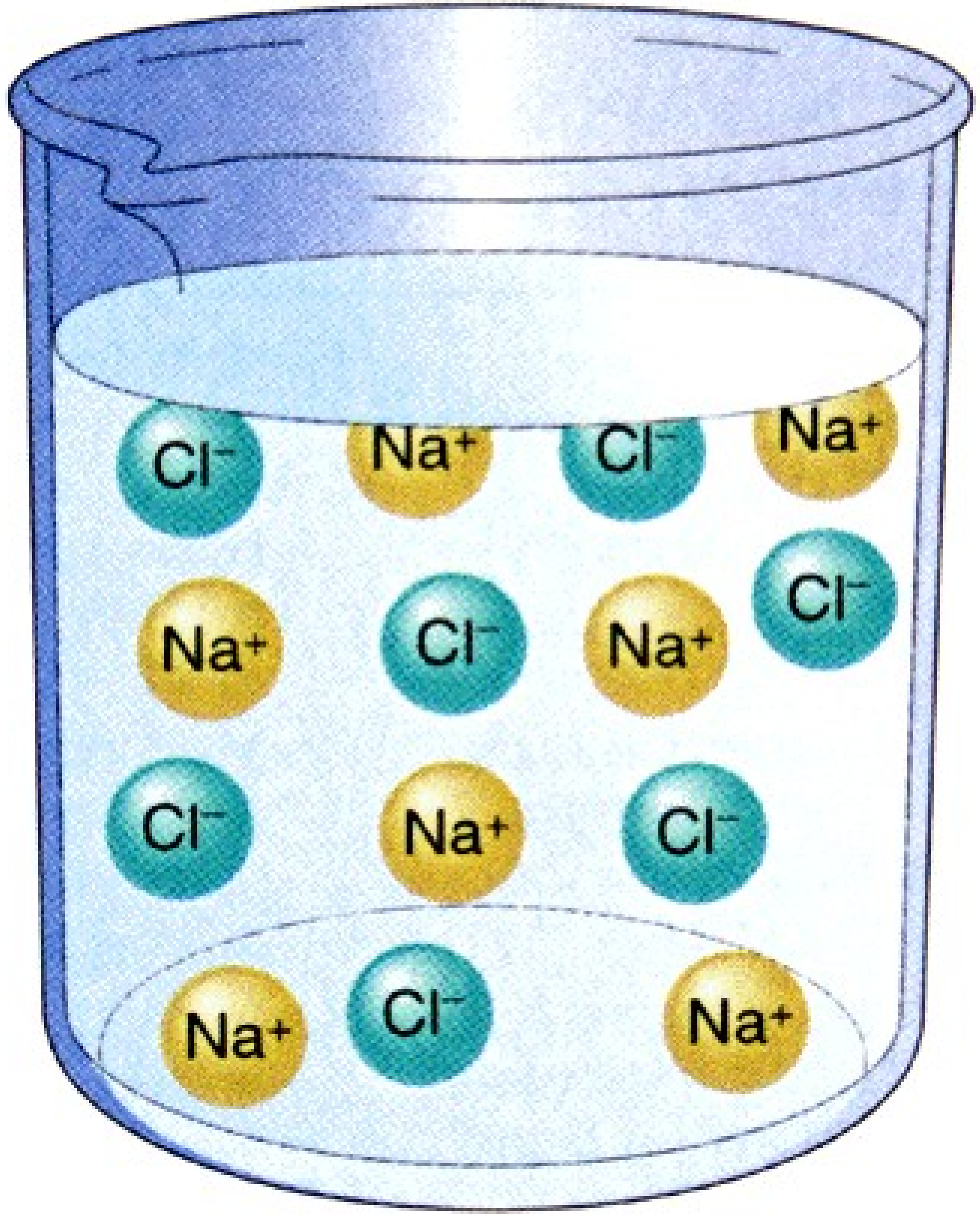
- *Anions* are negatively charged ions that have picked up one or more electrons that another atom has lost (they are electron acceptors).

- In general, ionic compounds exist as solids but some may dissociate into positive and negative ions in solution. Such a compound is called an *electrolyte*.- Table 2.2

Example of Diffusion.



Crystals of Table Salt.



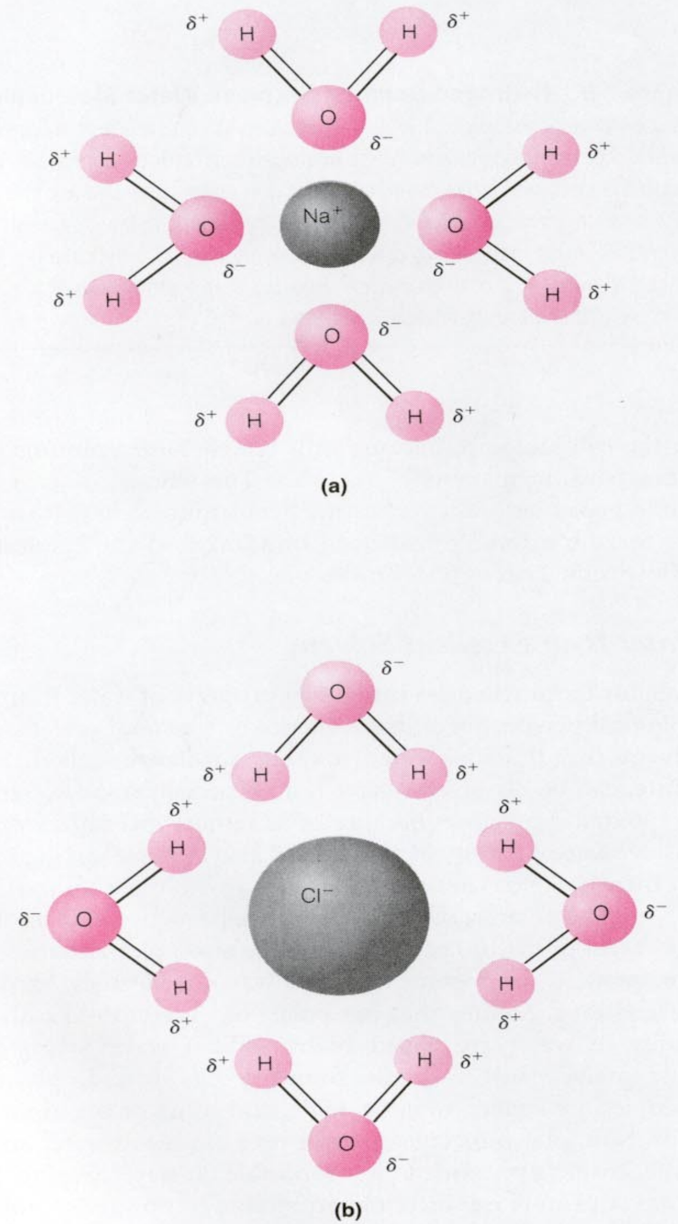


Figure 2-10 The Solubilization of Sodium Chloride.
Sodium chloride (NaCl) dissolves in water because of the formation of spheres of hydration around **(a)** the sodium ions and **(b)** the chloride ions. The oxygen atom and the sodium and chloride ions are drawn to scale.

Metabolism

- *Metabolism* refers to all the chemical reactions occurring in an organism.
- The total amount of energy present at the beginning and end of a chemical reaction is the same; energy can neither be created nor destroyed although it may be converted from one form to another (law of conservation of energy). - released as Heat, Water &/or Carbon Dioxide

Acid-Base Balance: The Concept of pH

- Body fluids must constantly contain balanced quantities of acids and bases.
- Biochemical reactions are very sensitive to even small changes in acidity or alkalinity.
- A solution's acidity or alkalinity is based on the pH scale, which runs from) (=10^0 = 1.0 moles H^+/L) to 14 (= 10^{-14} = 0.00000000000001 moles H^+/L) (Fig. 2.14)

Acid-Base Balance: The Concept of pH

- pH 7.0 = 10^{-7} = 0.0000001 moles H^+/L = neutrality or equal numbers of $[H^+]$ and $[OH^-]$.
- Values below 7 indicate acid solutions ($[H^+] > [OH^-]$).
- Values above 7 indicate alkaline solutions ($[H^+] < [OH^-]$).

Maintaining pH: Buffer Systems

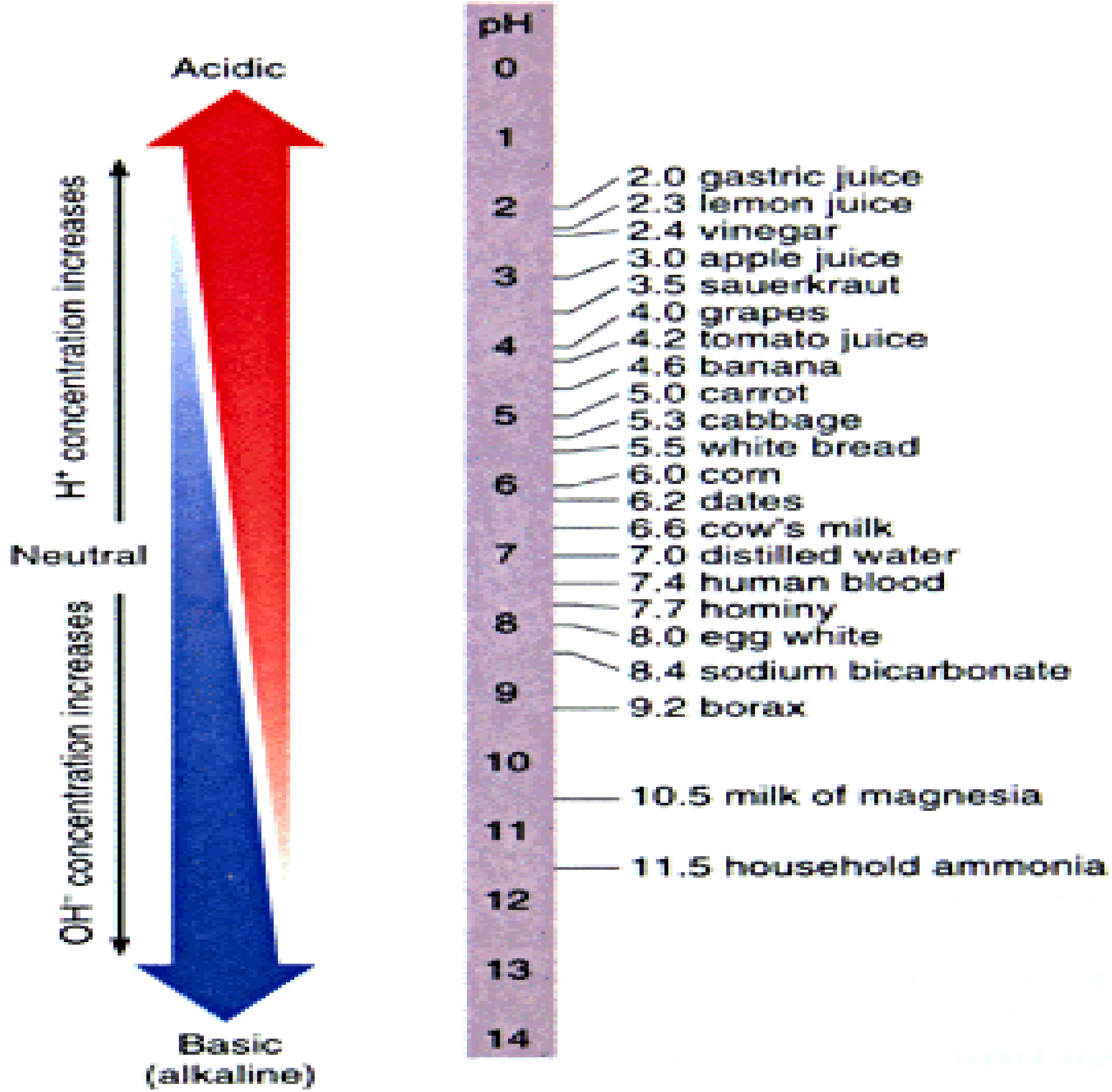
- The pH values of different parts of the body are maintained fairly constant by buffer systems, which usually consist of a weak acid and a weak base.
- The function of a buffer system is to convert strong acids or bases into weak acids or bases.

Maintaining pH: Buffer Systems

- One important buffer system in the body is the carbonic acid-bicarbonate buffer system.
- Bicarbonate ions (HCO_3^-) act as weak bases and carbonic acid (H_2CO_3) acts as a weak acid.
- $CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$

	pH	$[H^+]$ (moles/liter)	$[OH^-]$ (moles/liter)
	0	10^{0}	10^{-14}
	1	10^{-1}	10^{-13}
	2	10^{-2}	10^{-12}
INCREASINGLY ACIDIC	3	10^{-3}	10^{-11}
	4	10^{-4}	10^{-10}
	5	10^{-5}	10^{-9}
	6	10^{-6}	10^{-8}
NEUTRAL	7	10^{-7}	10^{-7}
	8	10^{-8}	10^{-6}
	9	10^{-9}	10^{-5}
	10	10^{-10}	10^{-4}
INCREASINGLY BASIC (ALKALINE)	11	10^{-11}	10^{-3}
	12	10^{-12}	10^{-2}
	13	10^{-13}	10^{-1}
	14	10^{-14}	10^{0}

Concentration of Hydrogen



CATALYSTS AND ENZYMES

Catalysts

- *Catalysts* are chemical compounds that speed up chemical reactions by lowering the **activation energy** needed for a reaction to occur (Fig. 2.11).
- A catalyst does not alter the difference in potential energy between the reactants and products. It only lowers the amount of energy needed to get the reaction started.

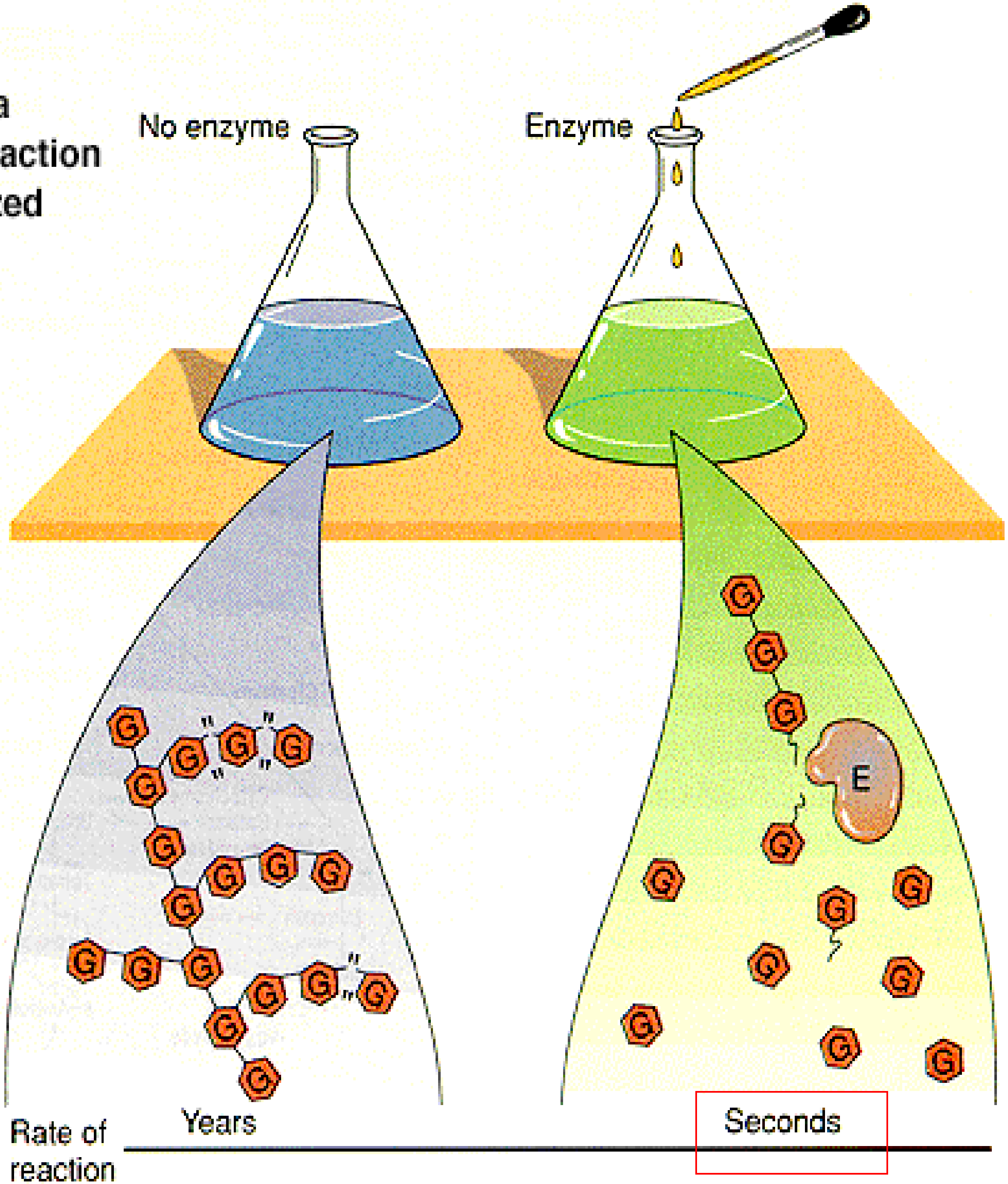
Catalysts

- A catalyst helps to properly orient the colliding particles of matter so that a reaction can occur.
- The catalyst itself is unchanged at the end of the reaction.

Enzymes

- Catalysts in living cells are called ***enzymes***.
  - The names of enzymes usually end in the suffix -*ase*; oxidase, kinase, and lipase, are examples.
  - Although enzymes catalyze select reactions, they do so with great efficiency and with many built-in controls.
  - Enzymes are highly *specific* in terms of the substrate with which they react.

Figure 7
Comparison of a noncatalyzed reaction versus a catalyzed reaction.



Activation energy

- *Activation energy* is the collision energy needed to break chemical bonds in the reactants (Fig. 2.10).
- This is the initial energy needed to start a reaction.
  - Factors that influence the chance that a collision will occur and cause a chemical reaction include:
    - Concentration
    - Temperature and Ph

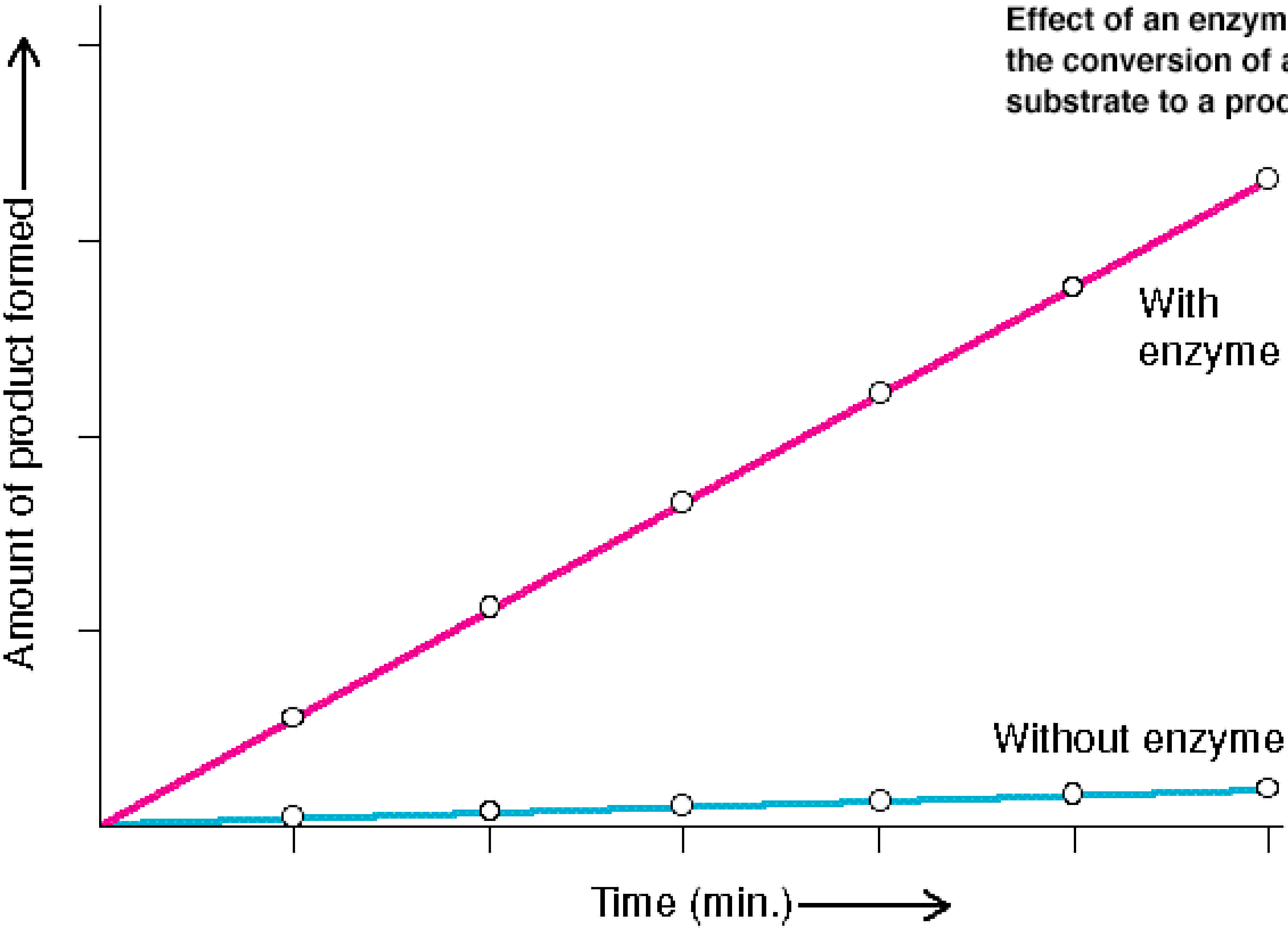


Figure 1
Effect of an enzyme on the conversion of a substrate to a product.

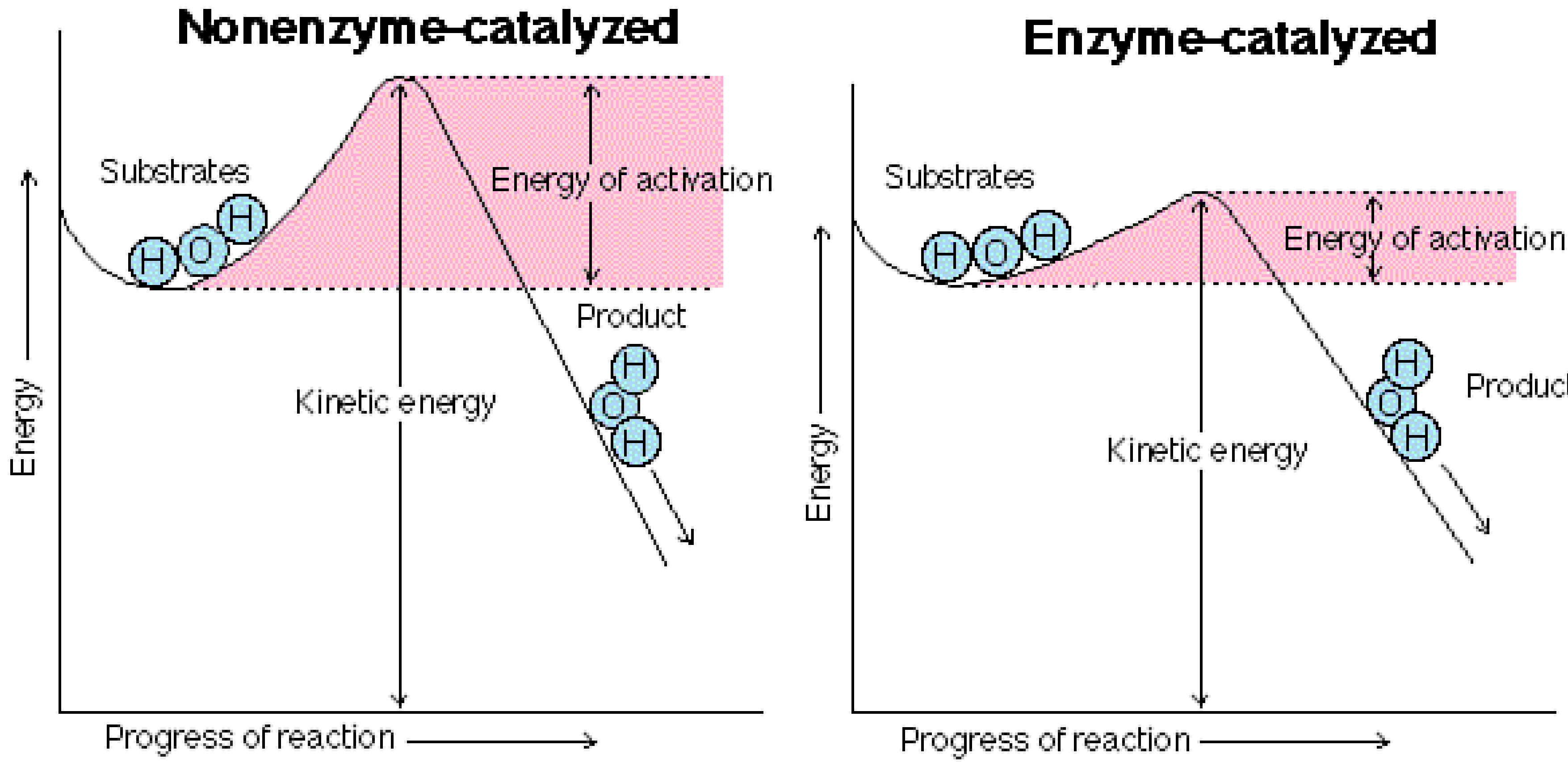
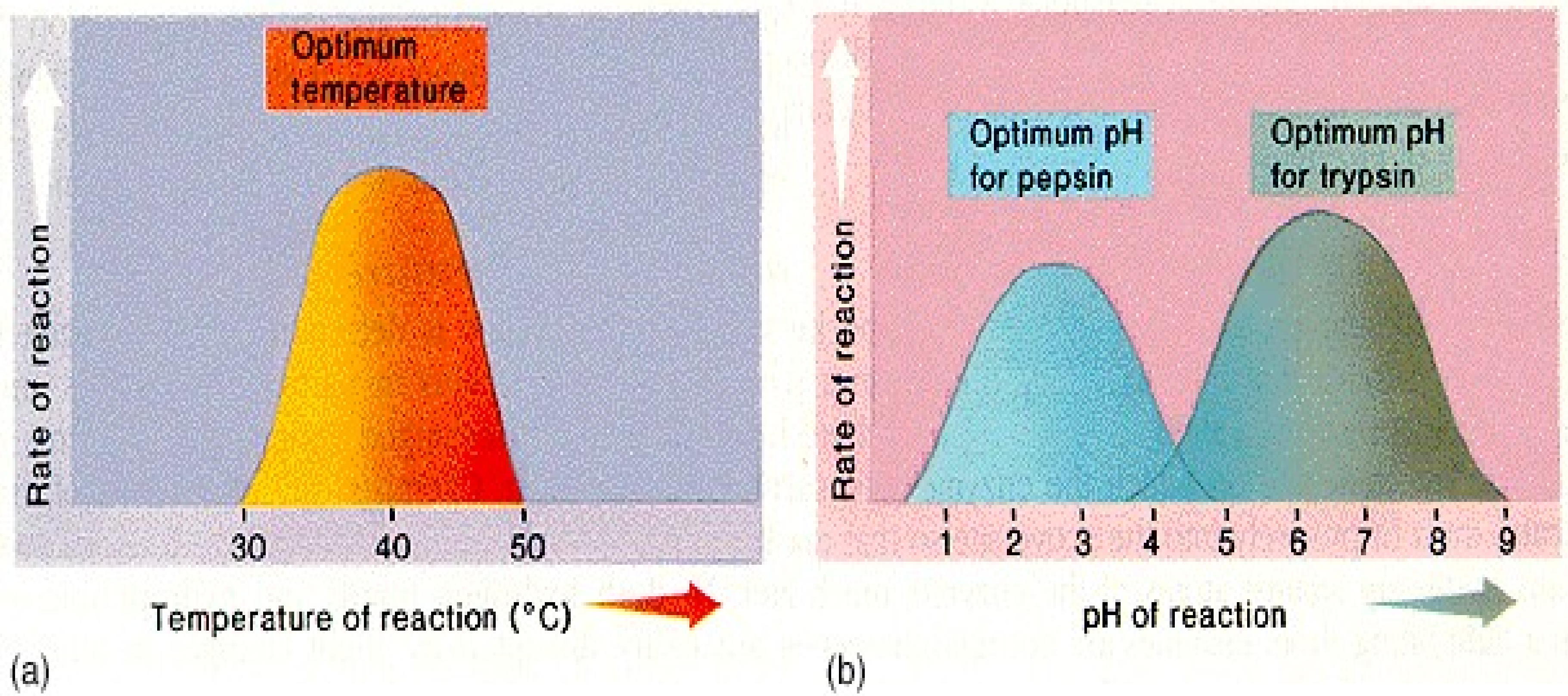


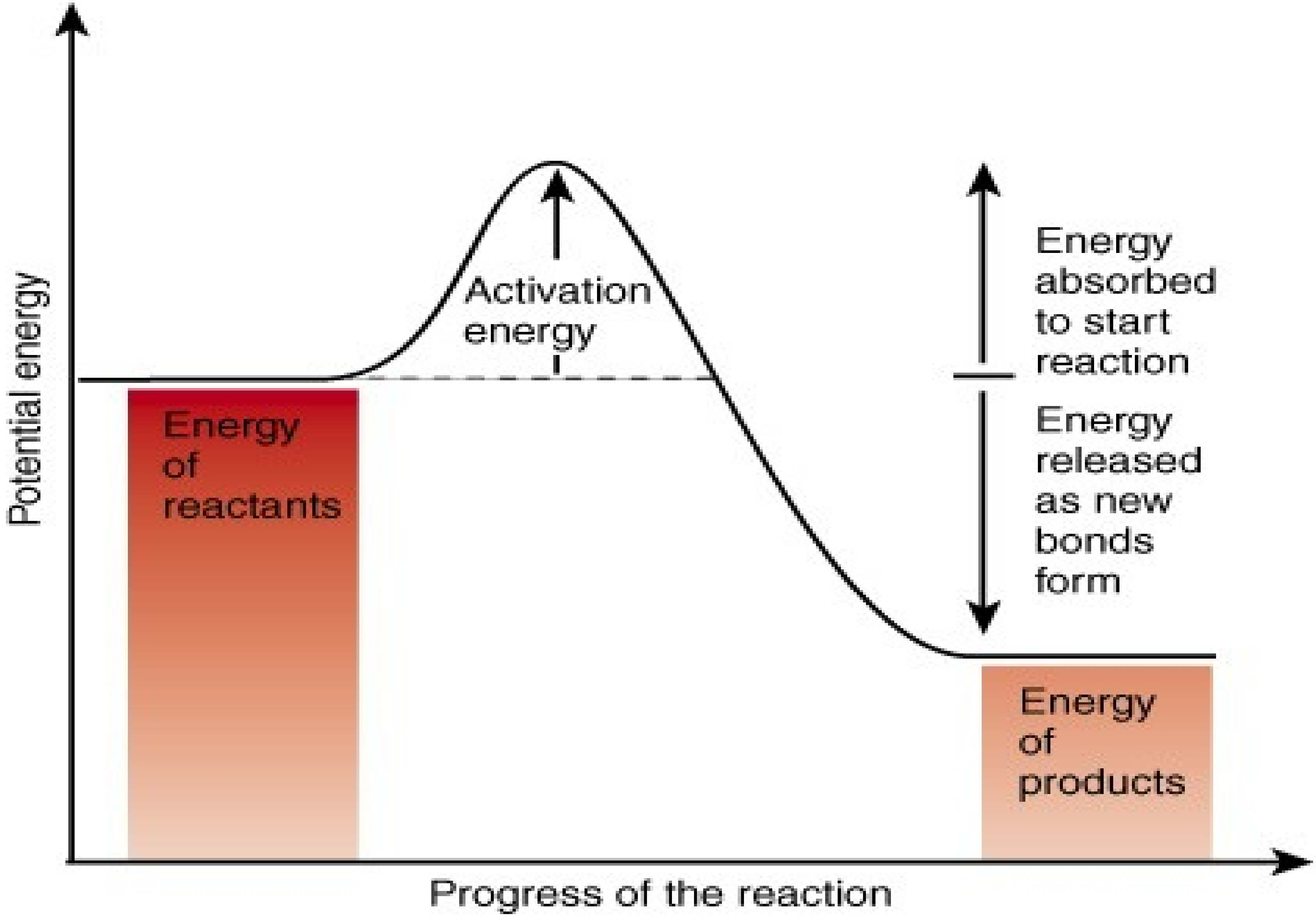
Figure 2
Energy barrier in chemical reactions.

Figure 4
Enzymes are sensitive to environmental conditions.



Enzymes

- Enzymes are extremely *efficient* in terms of the number of substrate molecules with which they react.
- Enzymes are subject to a great deal of cellular *control*s.
- Enzymes speed up chemical reactions by increasing frequency of collisions, lowering the activation energy and properly orienting the colliding molecules (Fig. 2.24).


Potential energy
Activation energy
Energy absorbed to start reaction
Energy released as new bonds form
Energy of reactants
Energy of products
Progress of the reaction

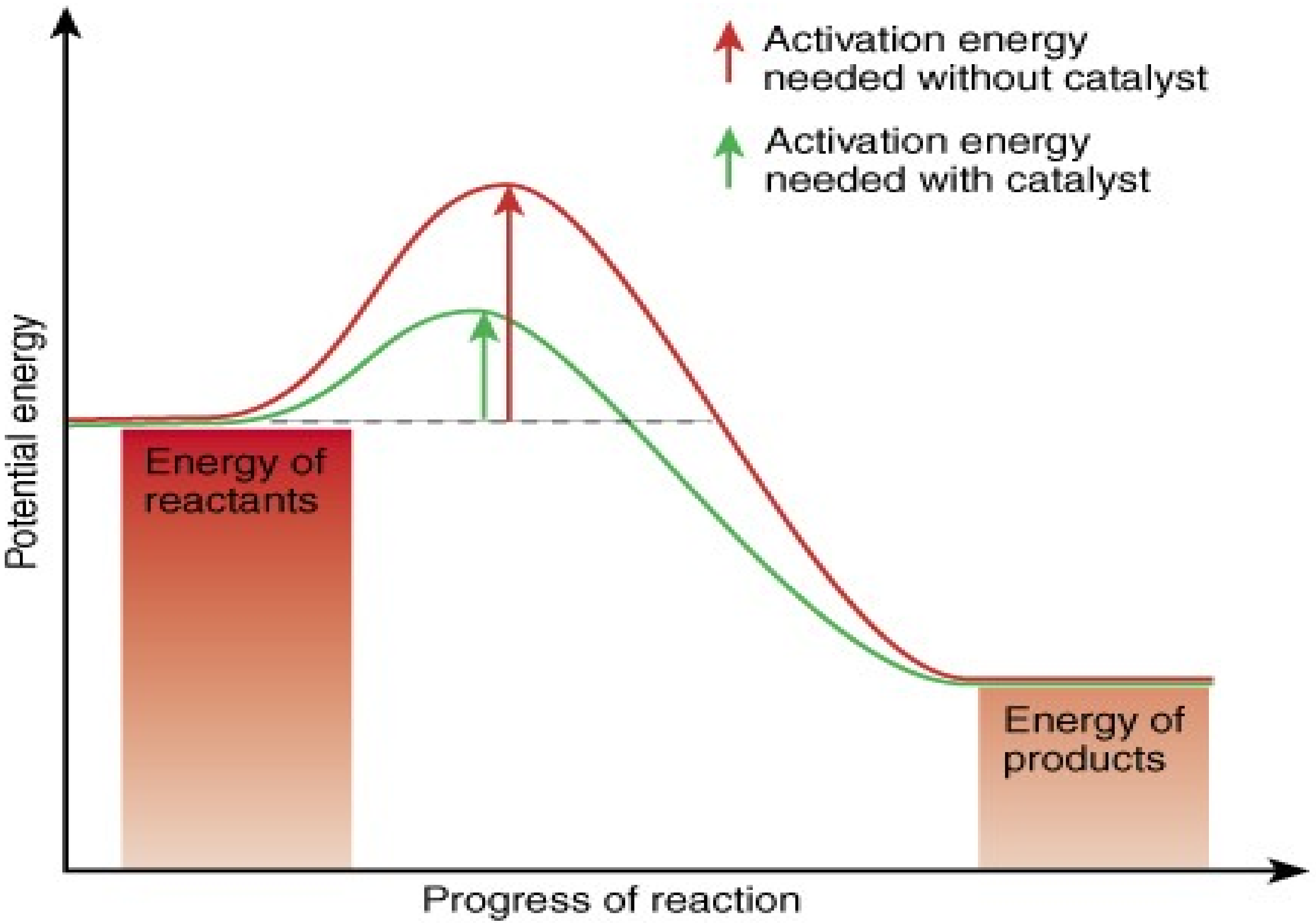
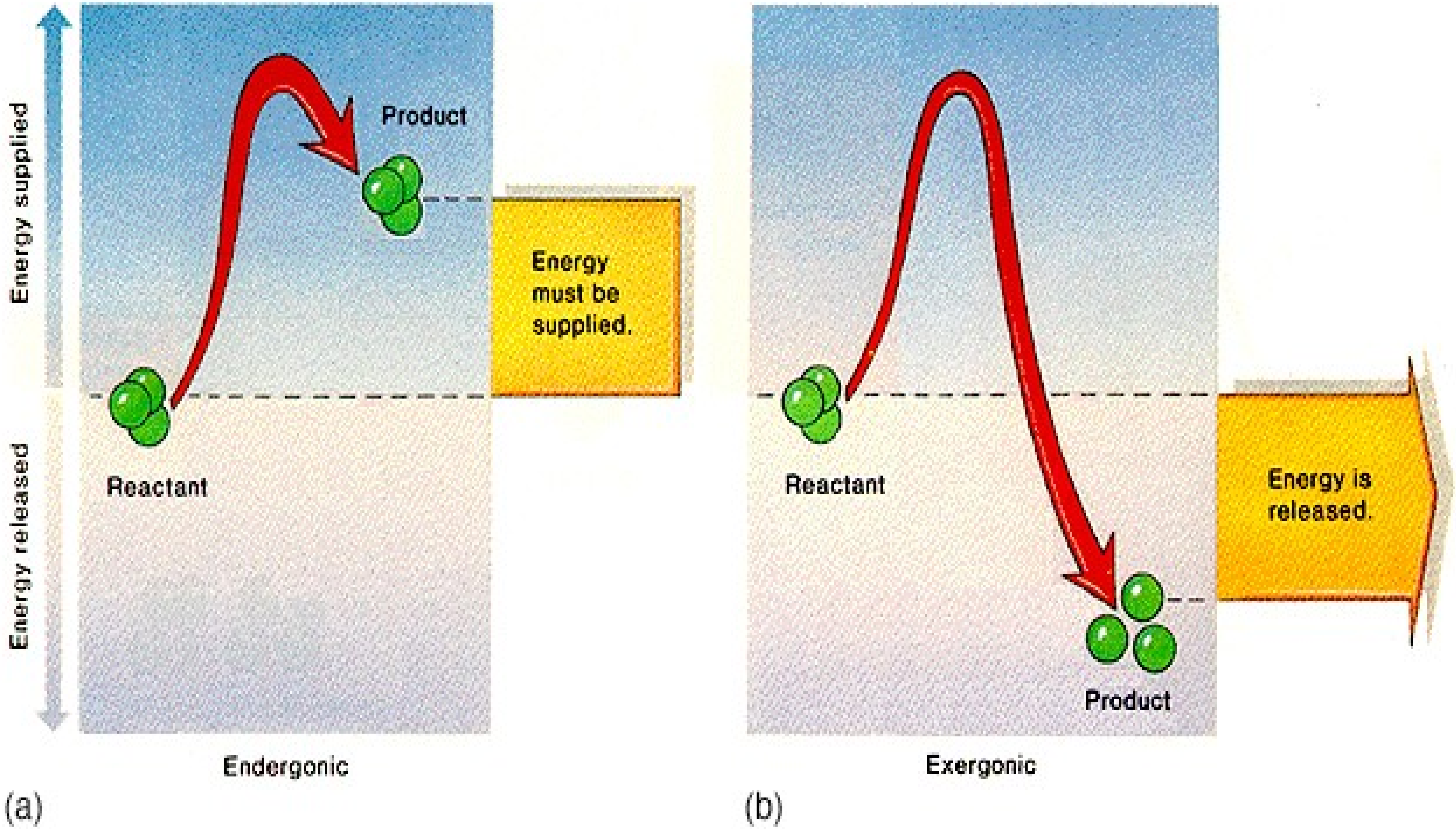

Activation energy needed without catalyst
Activation energy needed with catalyst
Potential energy
Energy of reactants
Energy of products
Progress of reaction

Figure 8
Energy in chemical reactions.



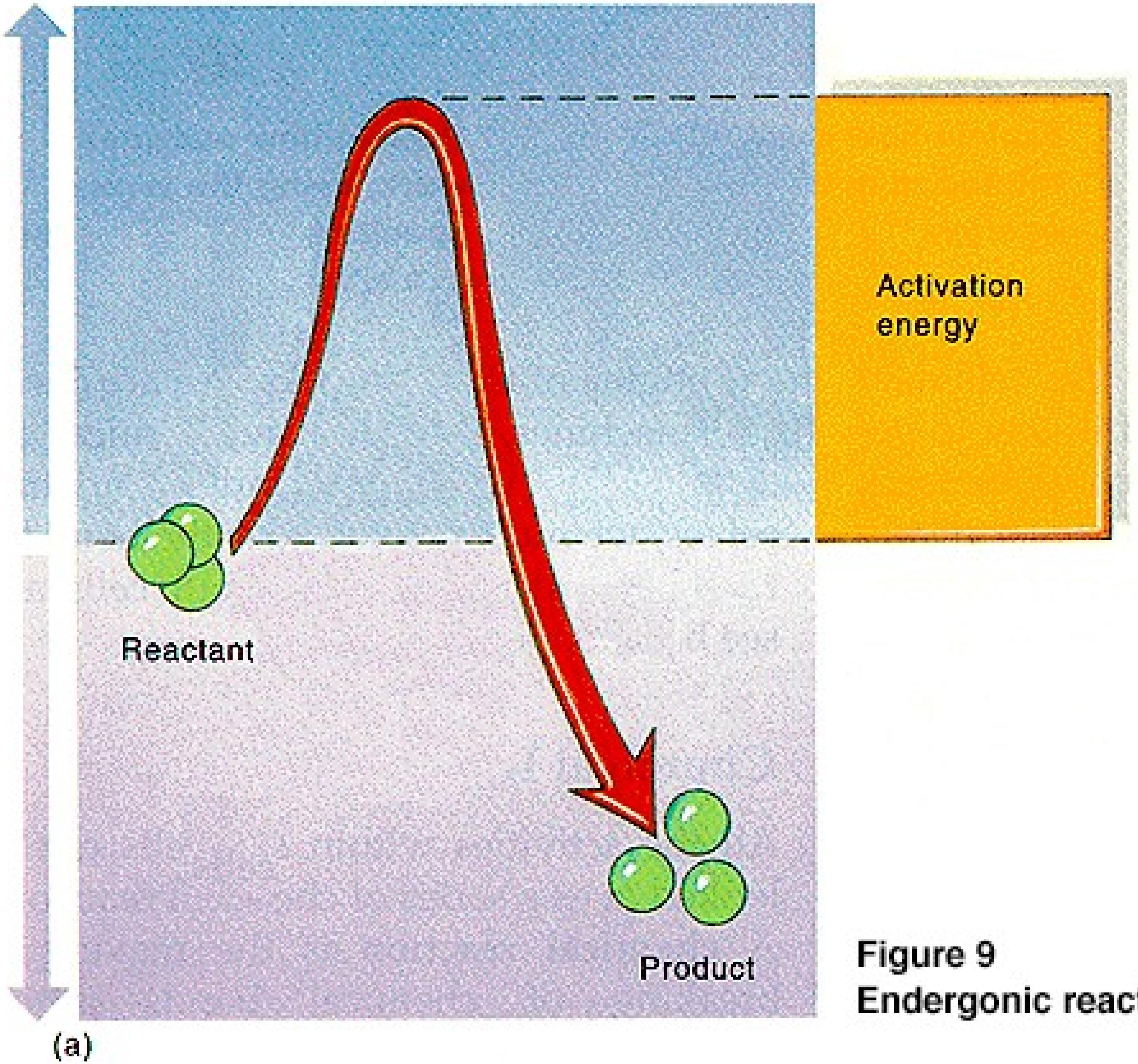


Figure 9
Endergonic reactions

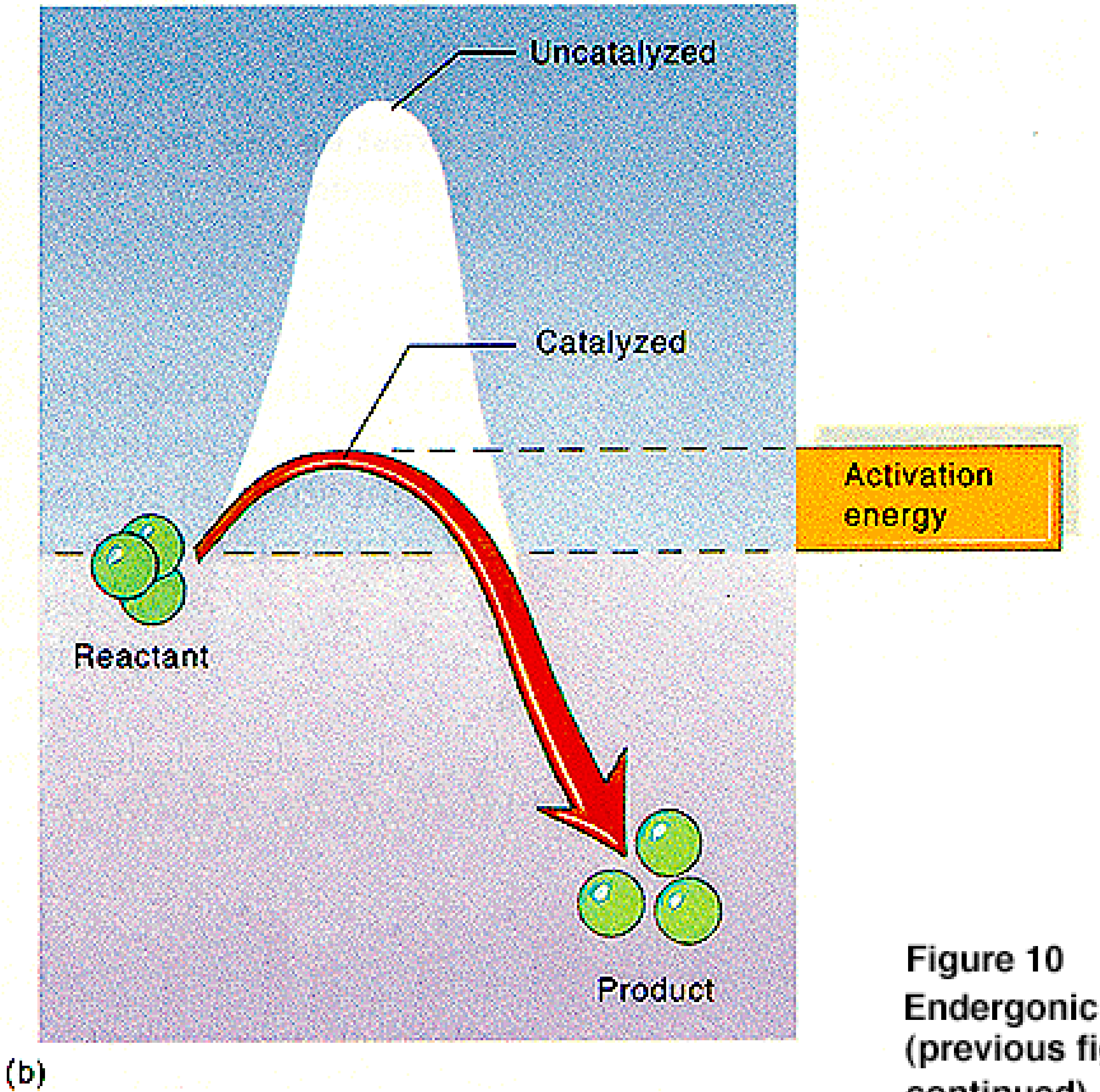


Figure 10
Endergonic reactions (previous figure continued)

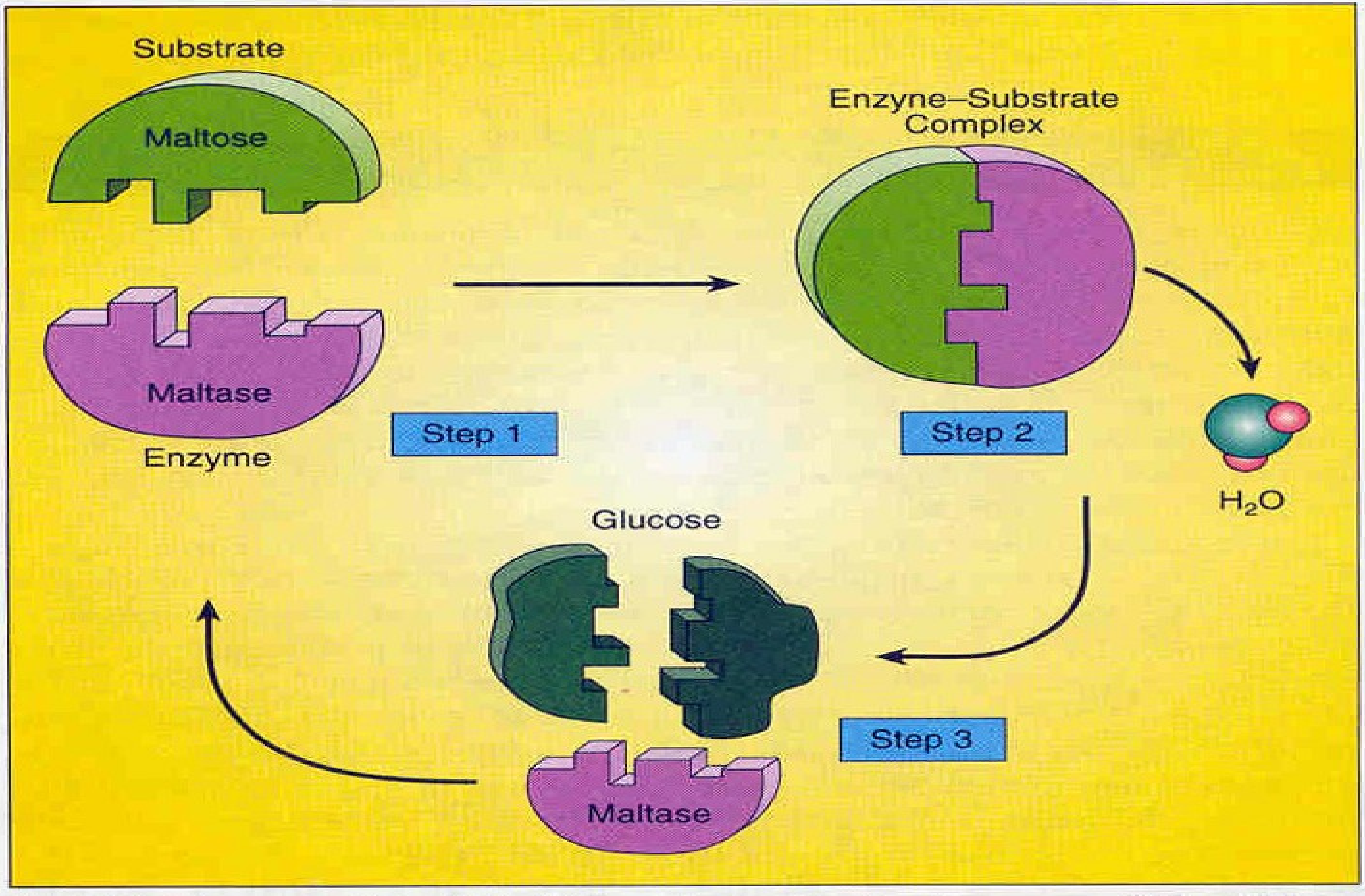
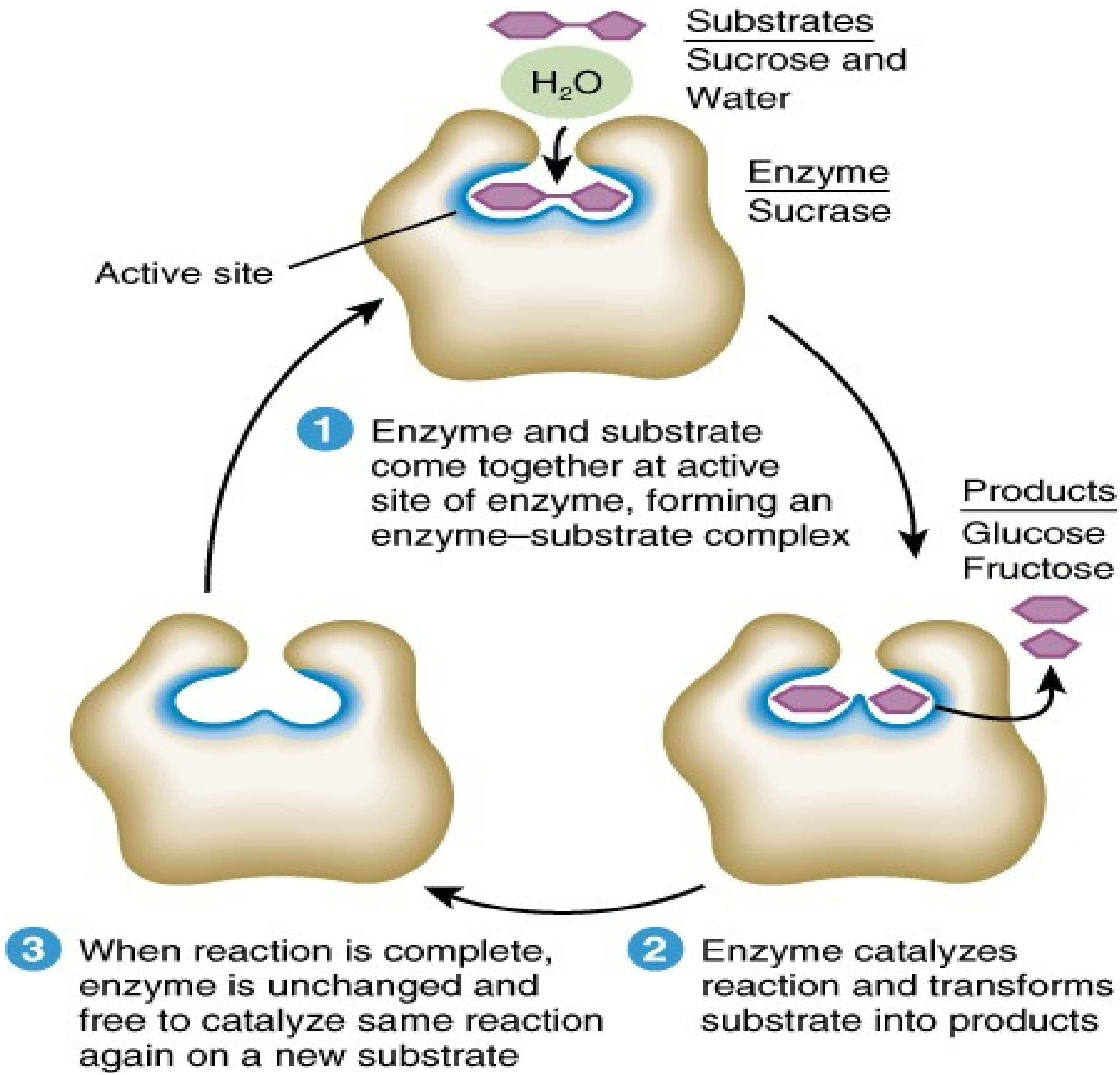
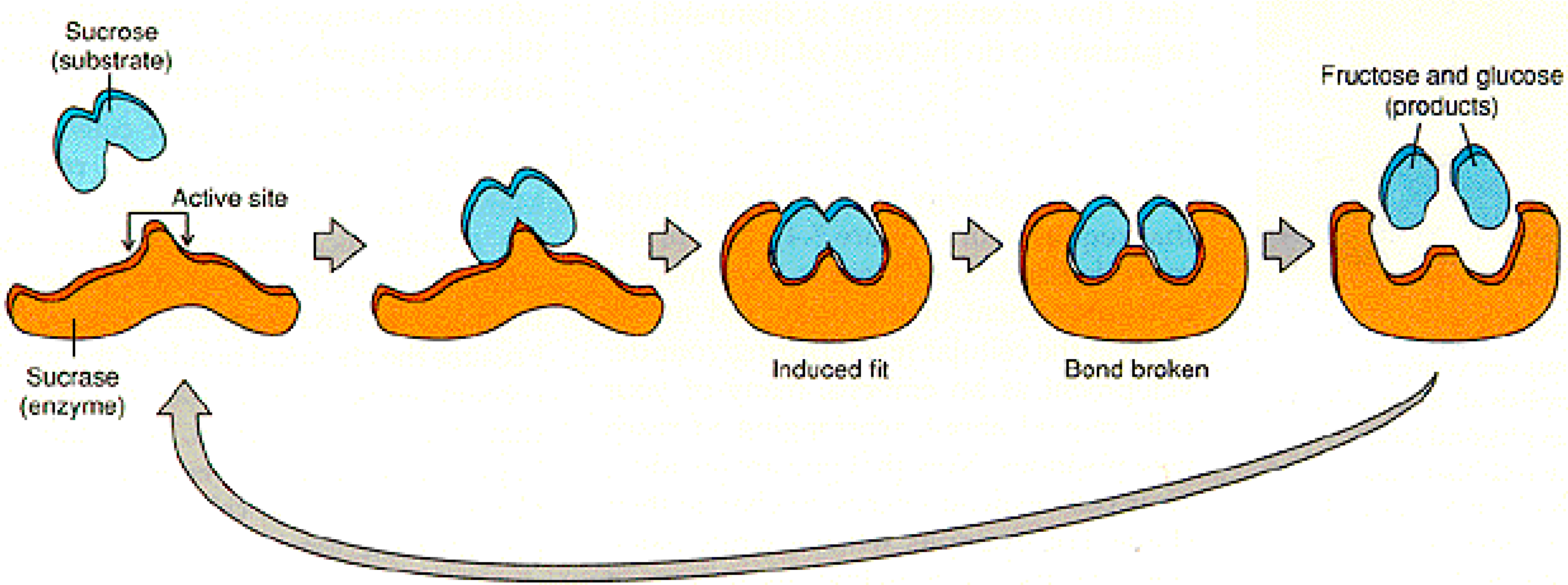


FIG. 1–19. Sequence of steps in the "lock and key" mechanism of an enzyme with its substrate. The example shows the formation of glucose following interaction of the enzyme maltase with its substrate maltose.



Substrates
Sucrose and
Water
H_2O
Enzyme
Sucrase
Active site
1 Enzyme and substrate come together at active site of enzyme, forming an enzyme–substrate complex
Products
Glucose
Fructose
3 When reaction is complete, enzyme is unchanged and free to catalyze same reaction again on a new substrate
2 Enzyme catalyzes reaction and transforms substrate into products

Figure 11
Catalysis of the reactant or substrate molecule sucrose.



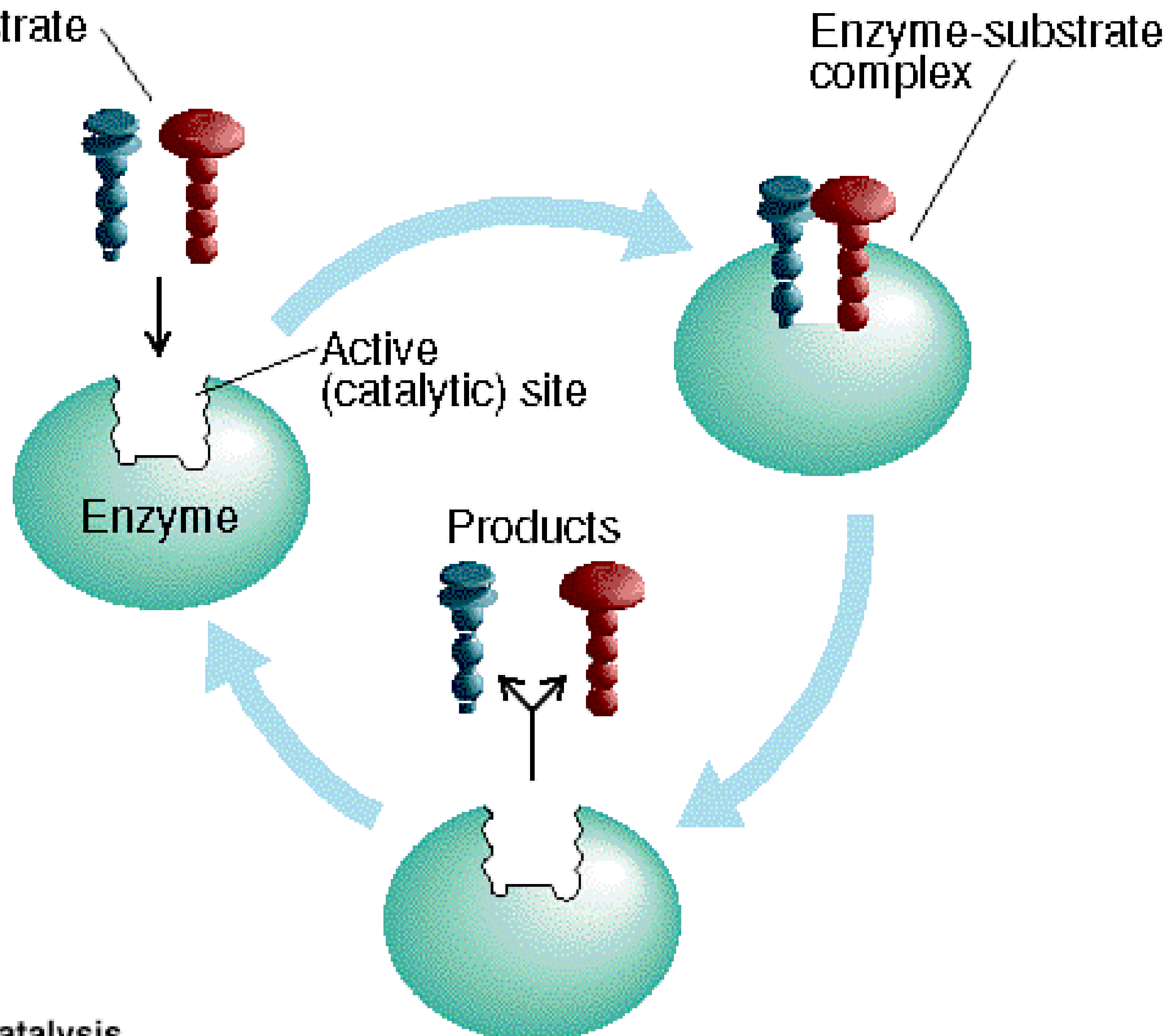
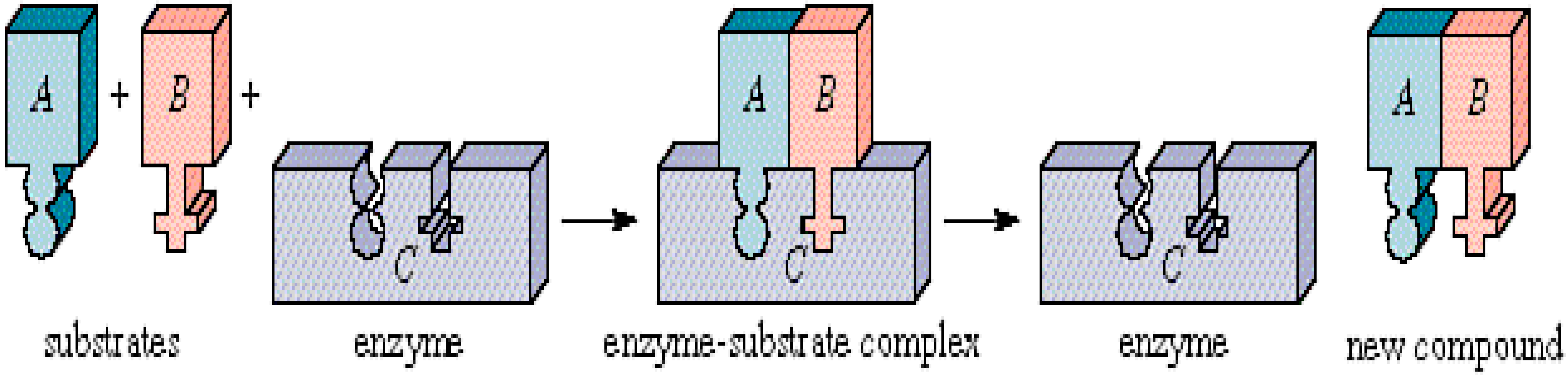


Figure 2
Enzyme catalysis.

Enzyme action.



Enzyme-catalyzed synthesis and hydrolysis reactions.

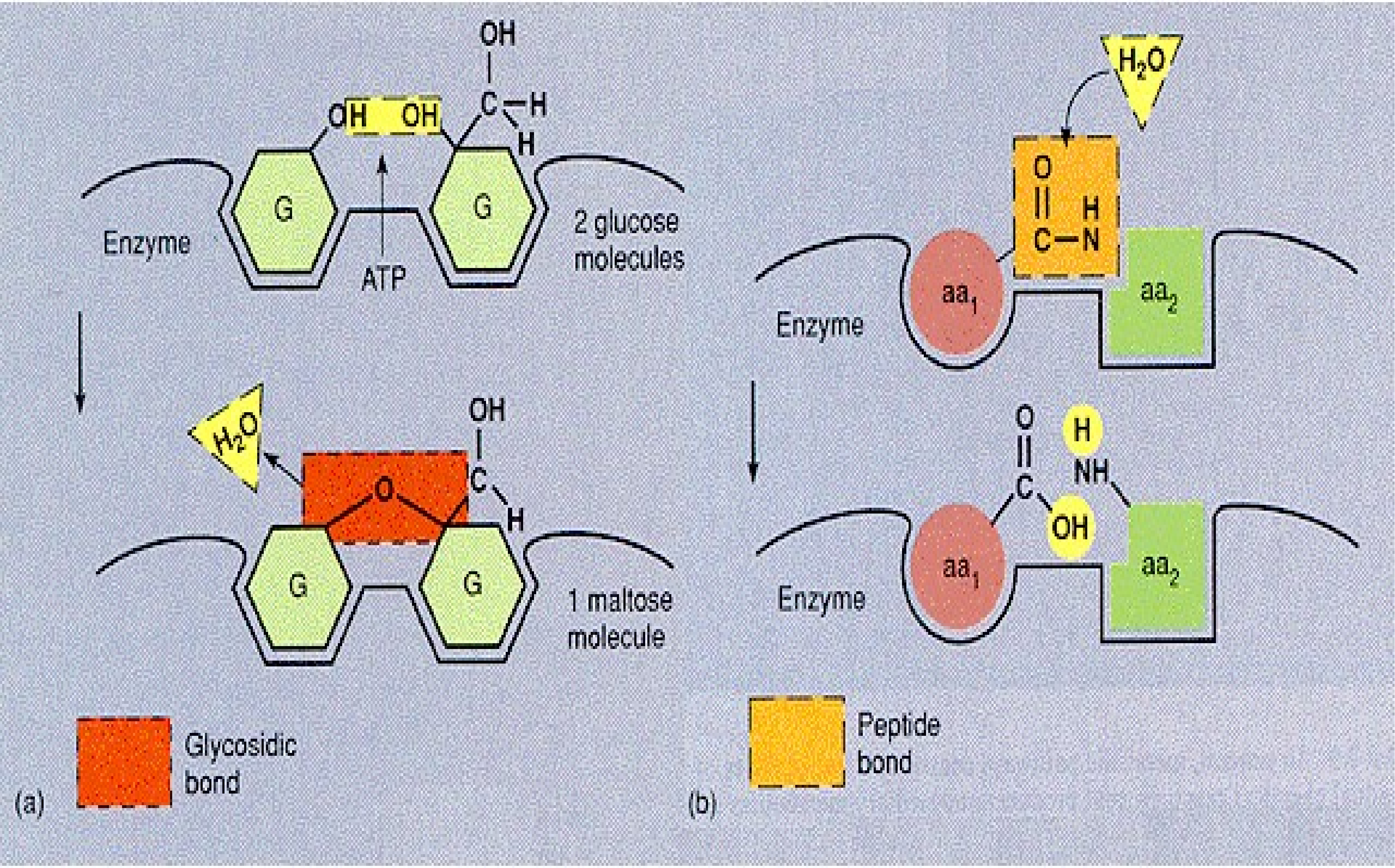


Figure 9
Enzyme-substrate reactions: fit, proximity, and orientation.

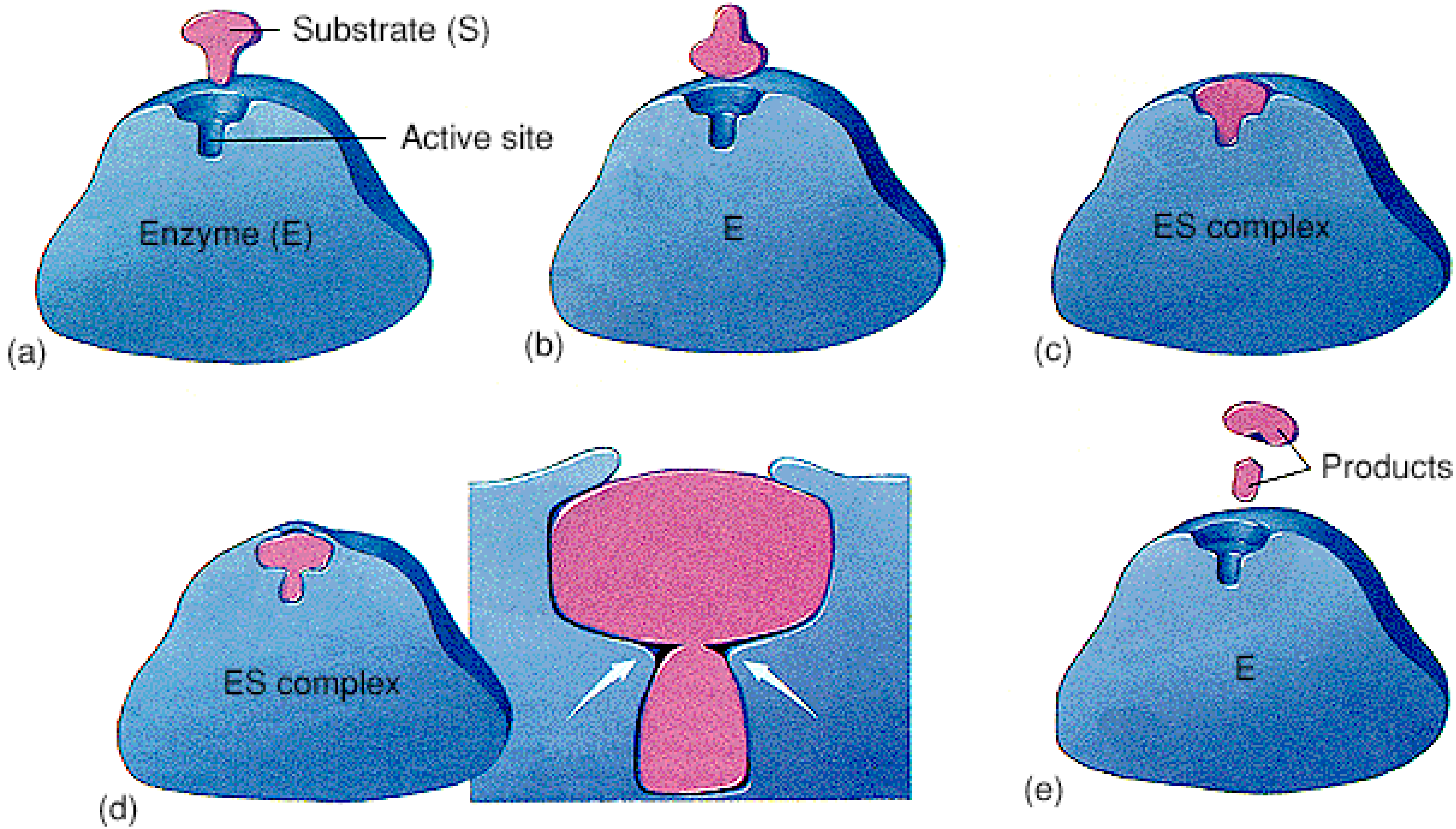


Figure 8
The catalytic cycle of an enzyme.

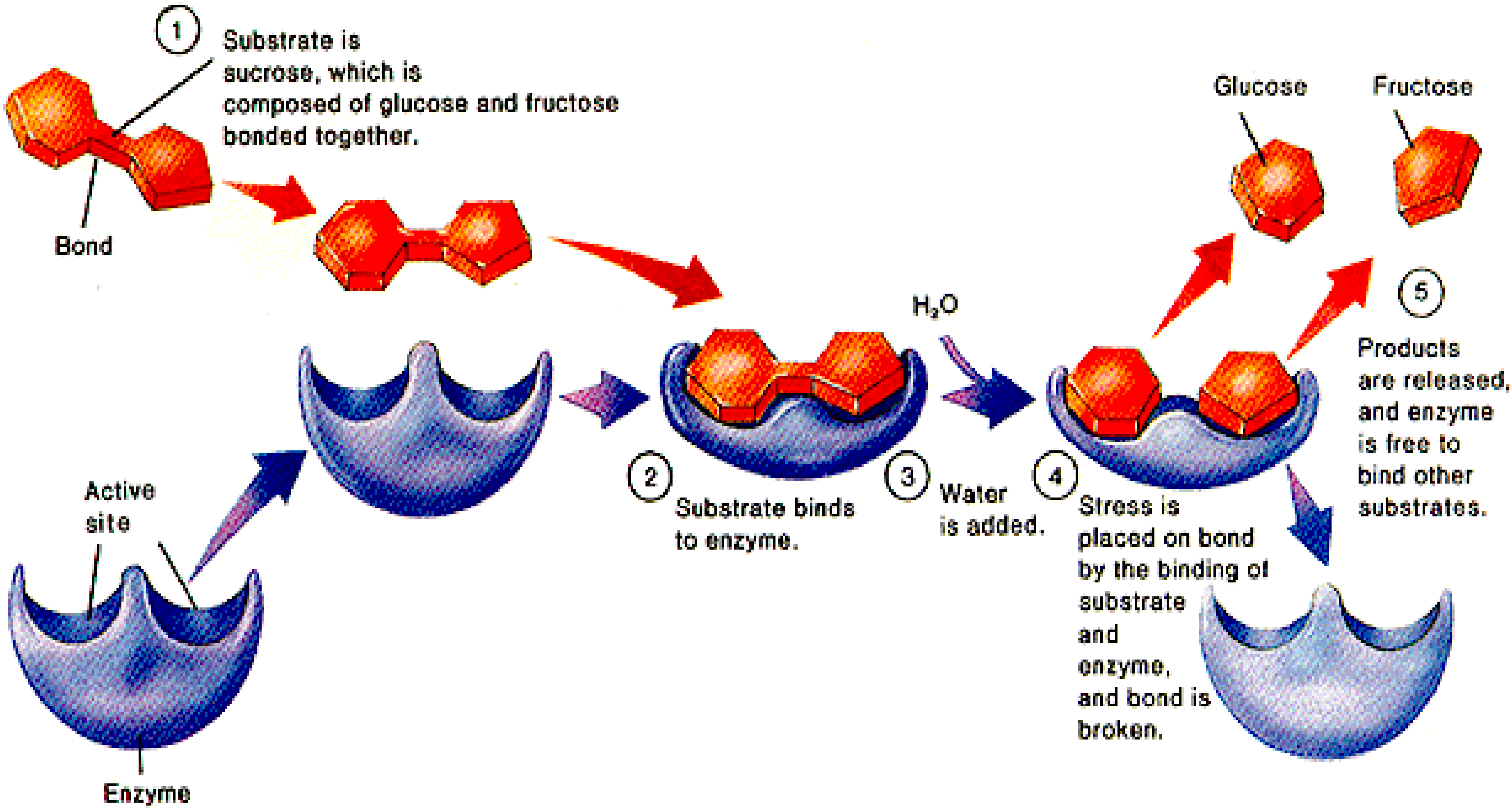
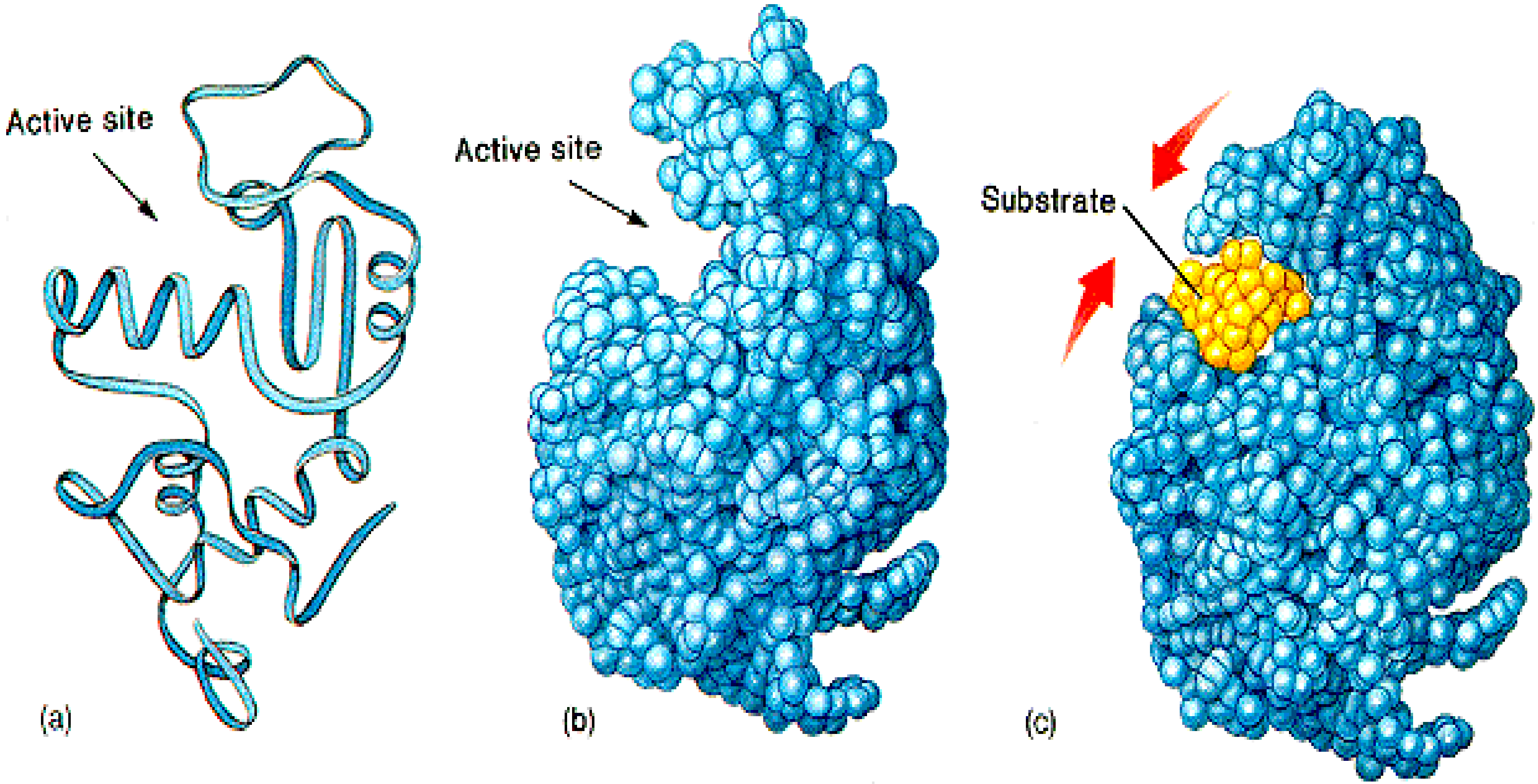


Figure 10
The induced-fit model of enzyme action.



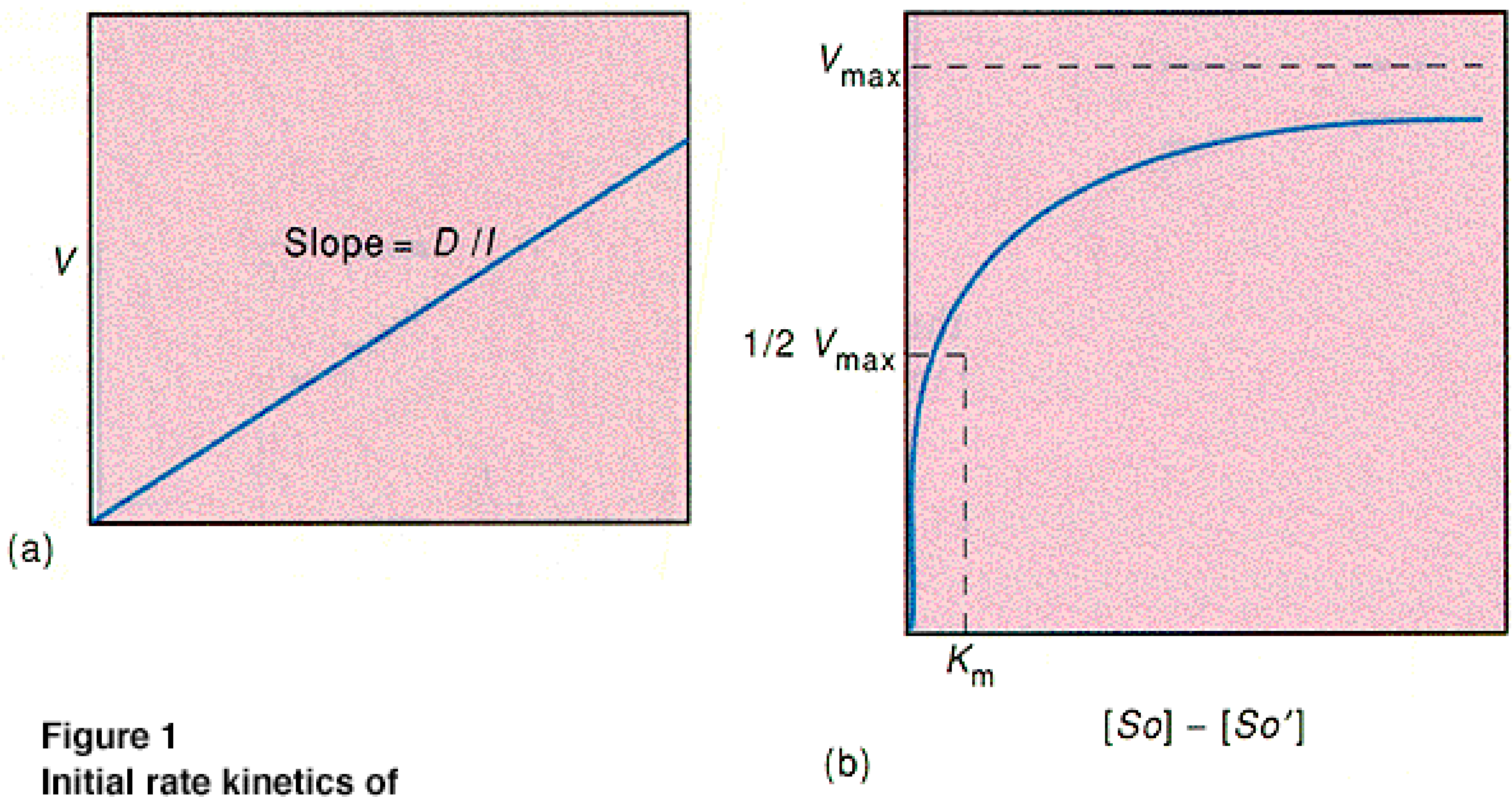
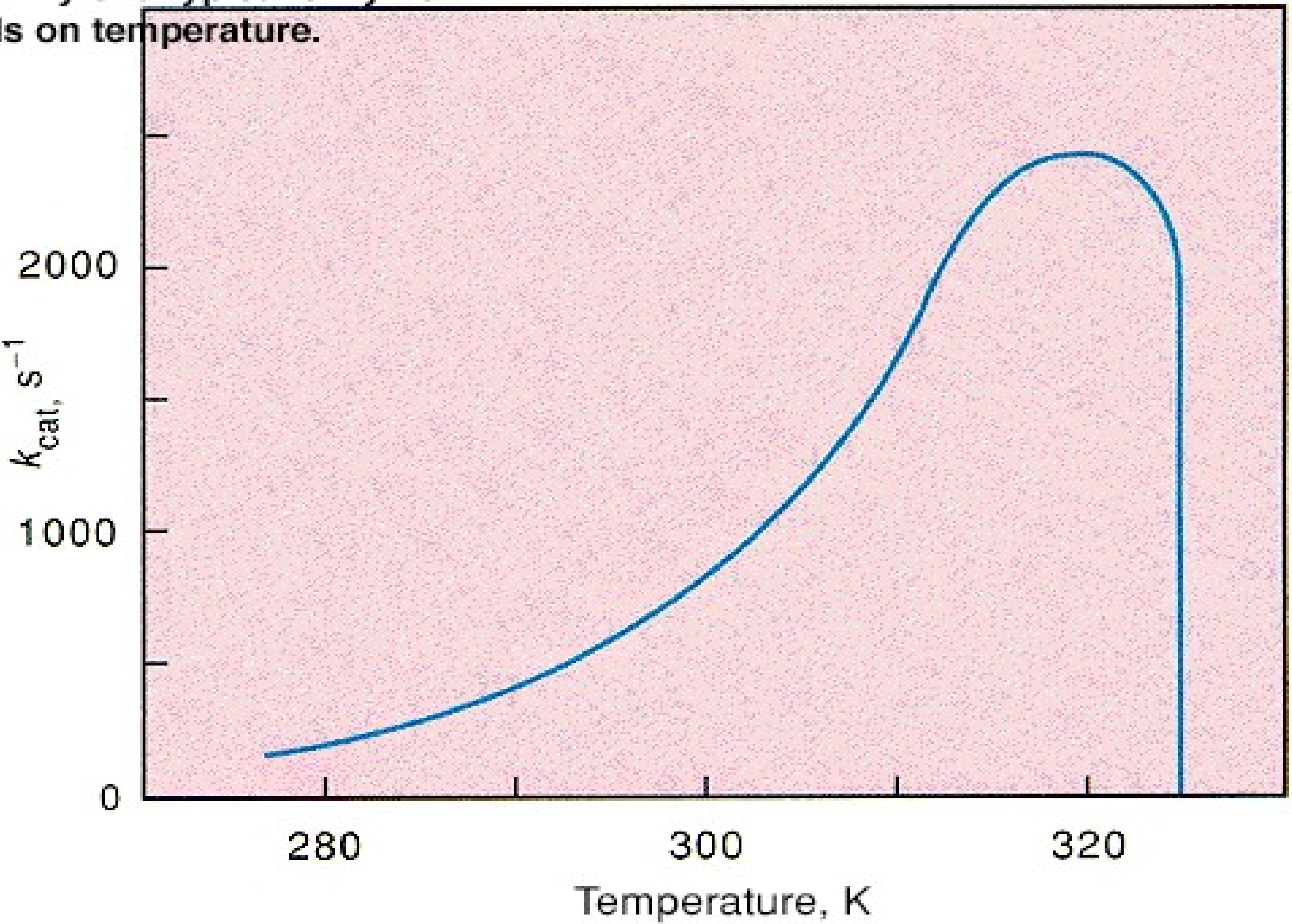
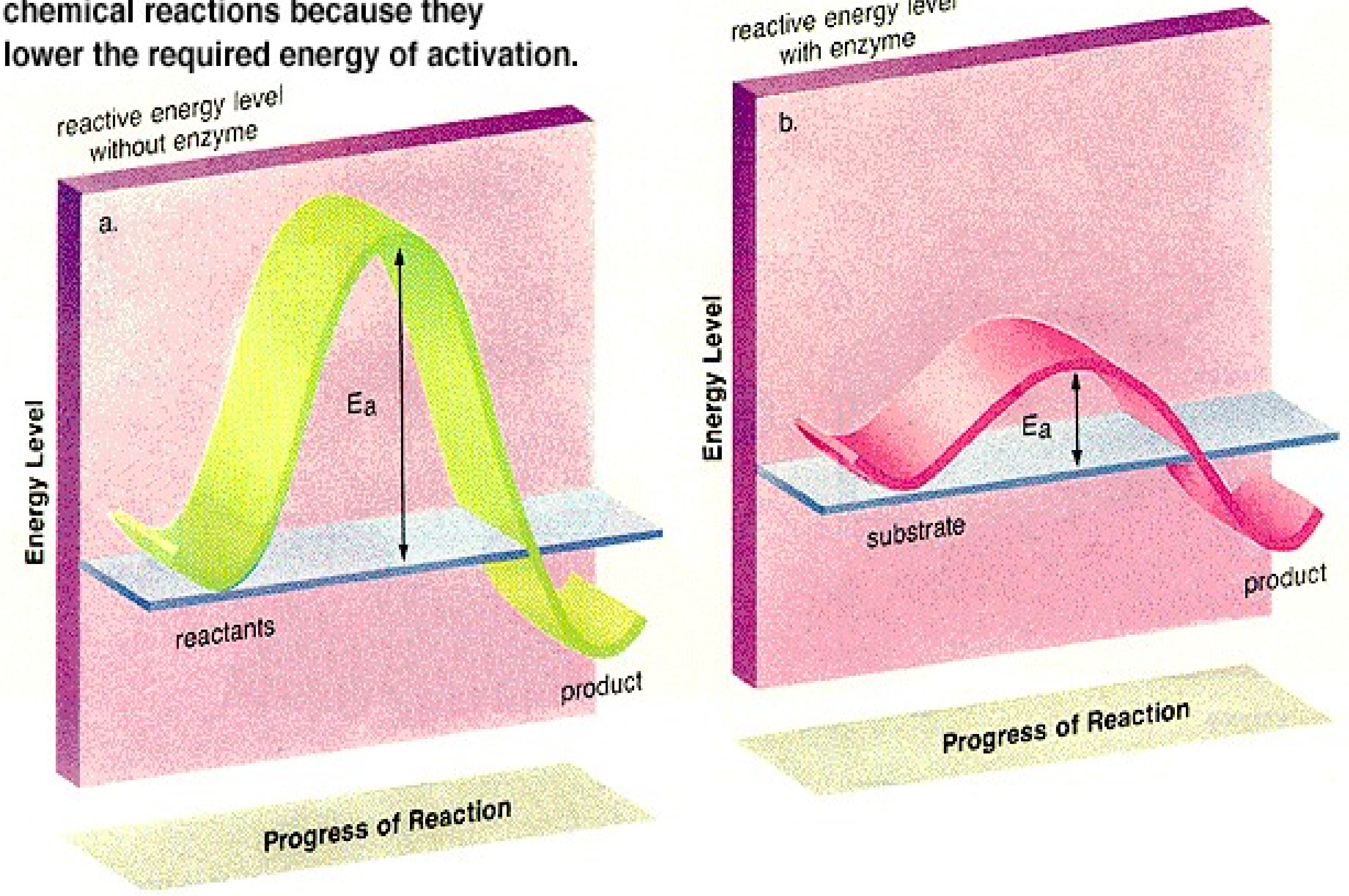


Figure 1
Initial rate kinetics of (a) simple diffusion and (b) carrier-mediated transport.

Figure 7
The activity of a typical enzyme depends on temperature.



Enzymes speed up the rate of chemical reactions because they lower the required energy of activation.



Organic Compounds

- Carbohydrates = Starches
- Lipids = Fats
- Proteins
- Nucleic Acids (DNA & RNA)

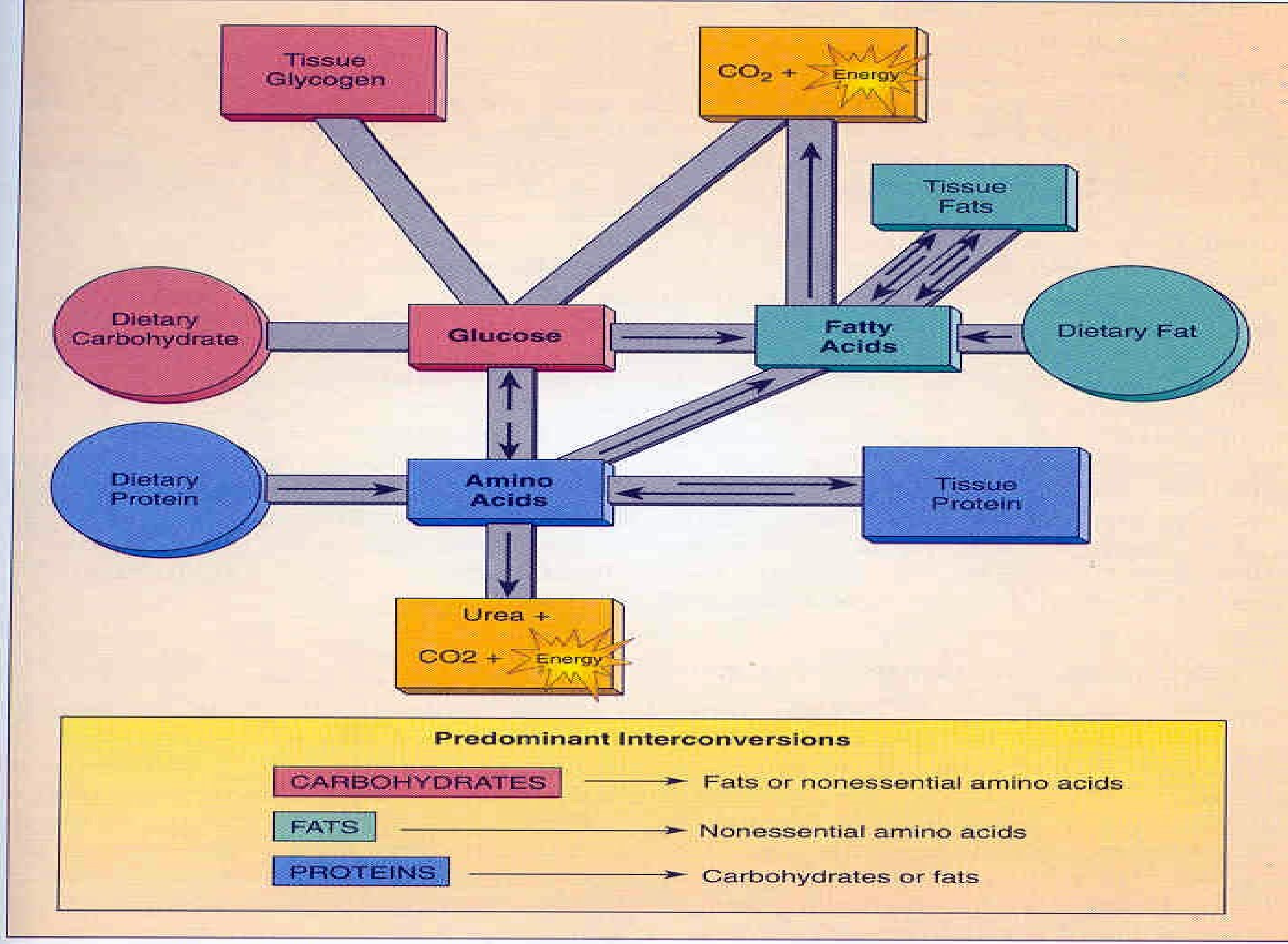


FIG. 11–5. The metabolic mill: interconversions between carbohydrates, lipids, and proteins.

Carbohydrates

- *Carbohydrates* provide most of the energy needed for life and include sugars, starches, **glycogen**, and cellulose.
- Some carbohydrates are converted to other substances which are used to build structures and to generate **ATP**.
- Other carbohydrates function as <u>food reserves.</u>

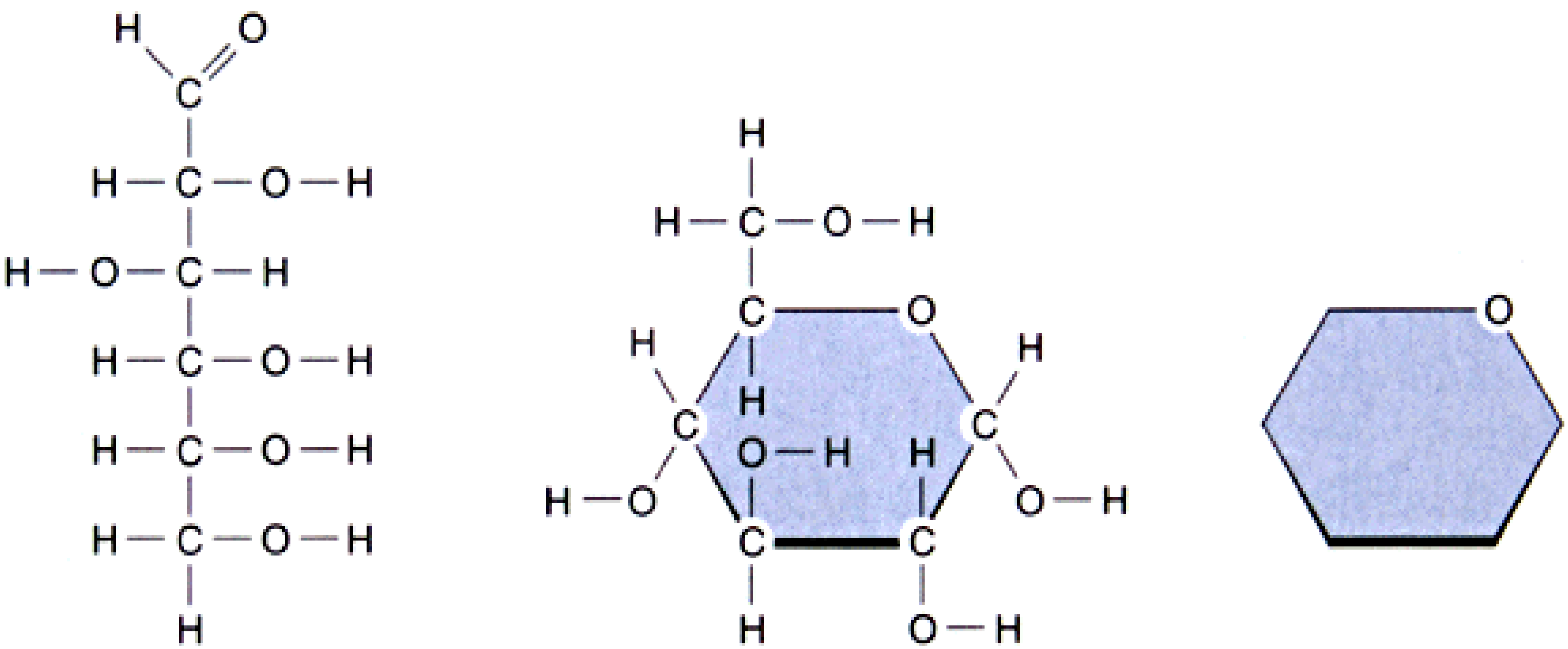
Carbohydrates

- The general structural rule for carbohydrates is one carbon atom for each water molecule (CH_2O) in a 2:1 ratio of hydrogen & oxygen and makup about 1 to 2% of the cells mass
- Carbohydrates are divided into three major groups based on their size: monosaccharides, disaccharides, and polysaccharides (Table 2.6) base on size and solubility.

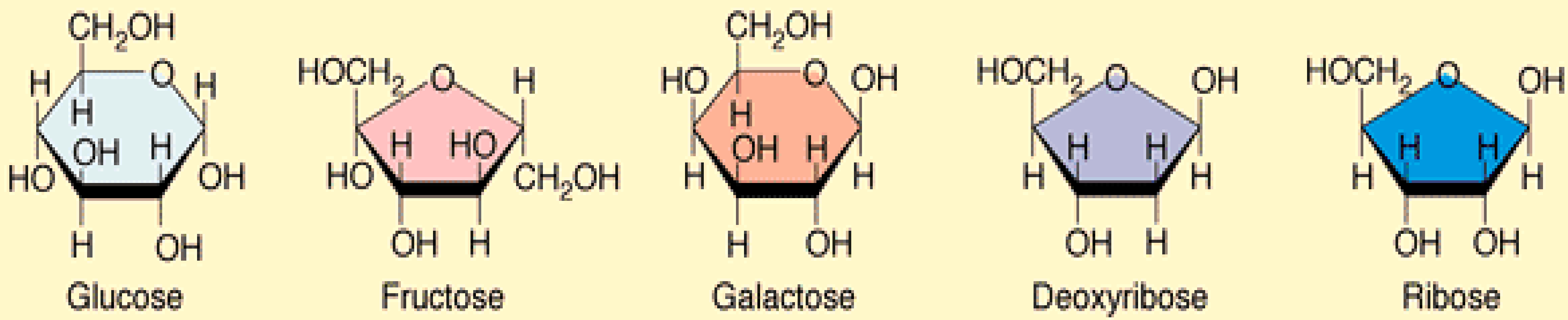
Carbohydrates

- Monosaccharides and Disaccharides: The Simple Sugars
  - **Monosaccharides** contain from three to seven carbon atoms and include glucose, a hexose that is the main energy-supplying compound of the body.
  - **Disaccharides** are formed from two monosaccharides by dehydration synthesis; they can be split back into simple sugars by hydrolysis (Fig 2.16). Glucose and fructose combine, for example, to produce sucrose.

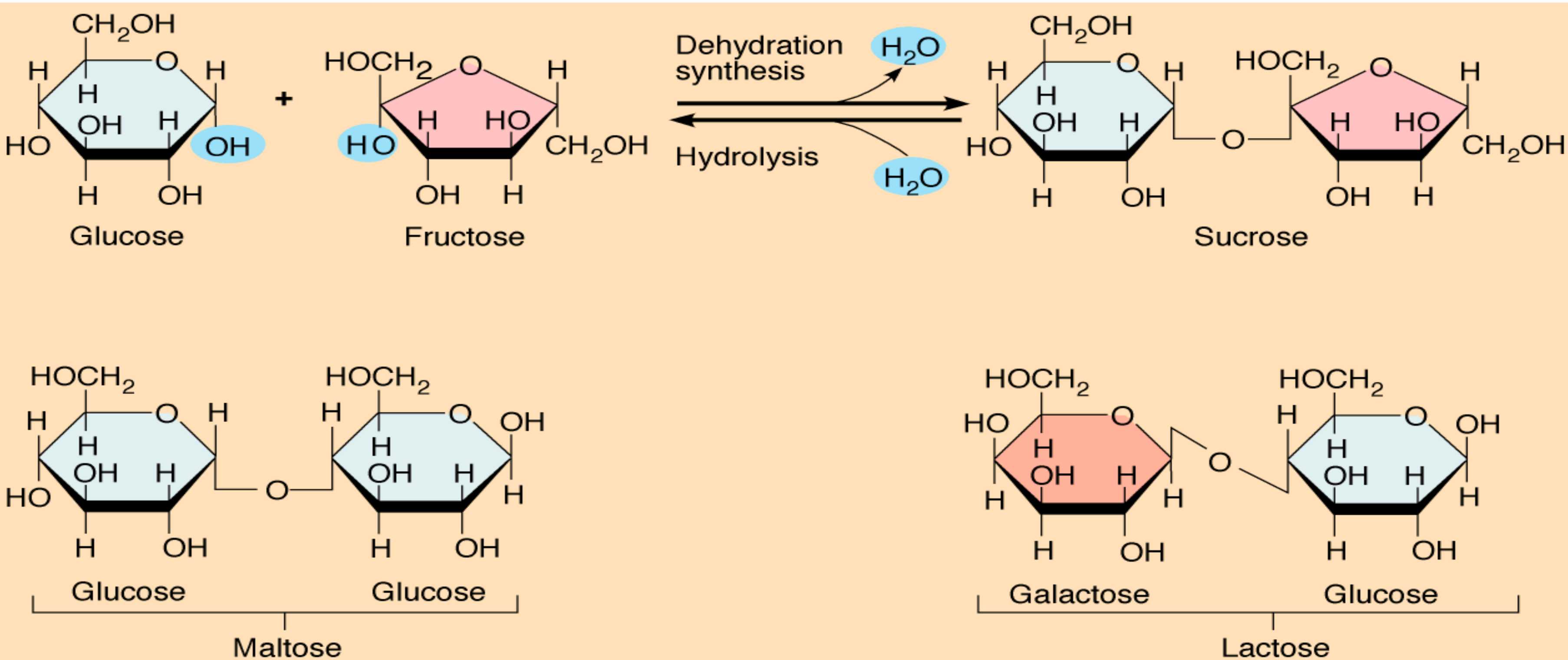
Monosaccharide Glucose.



(a) (b) (c)



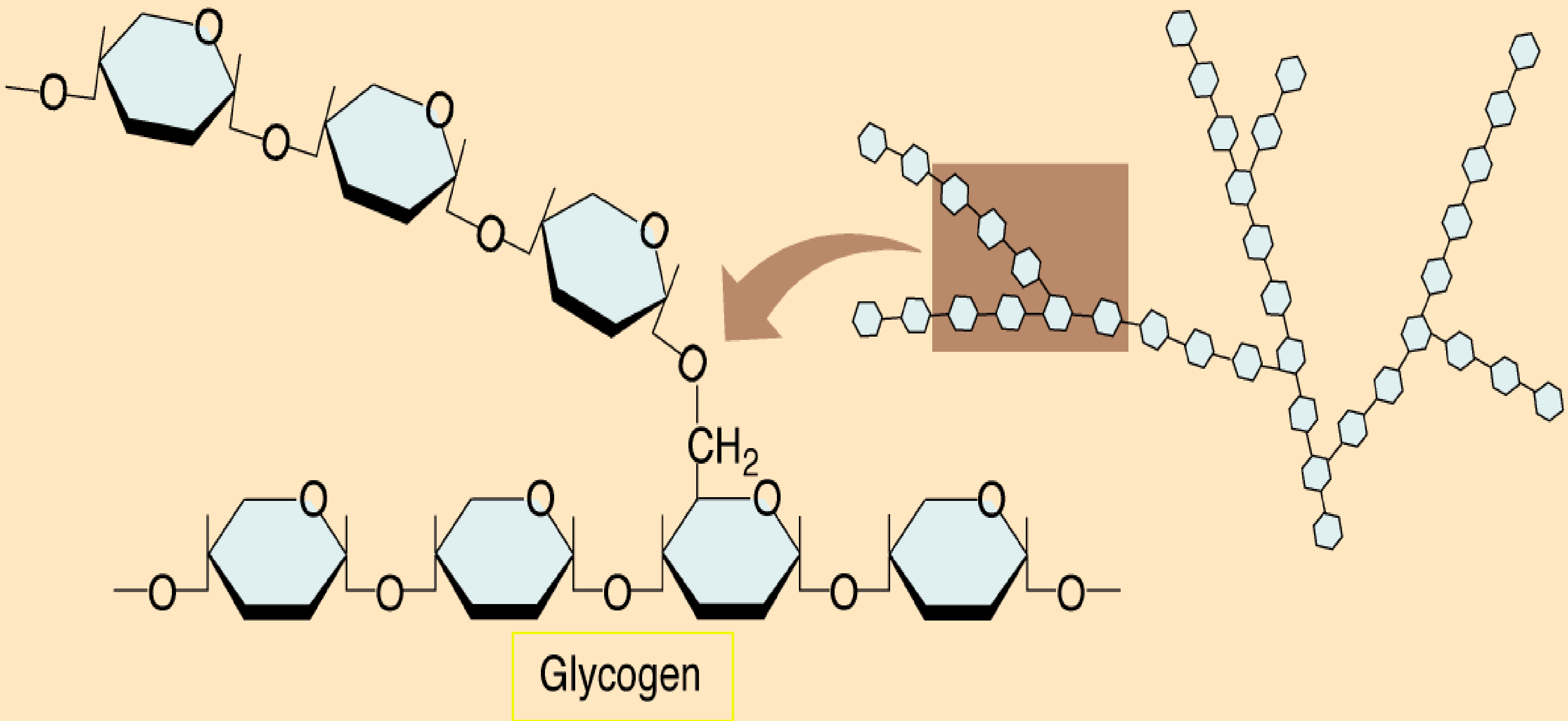
(a) Monosaccharides



(b) Disaccharides

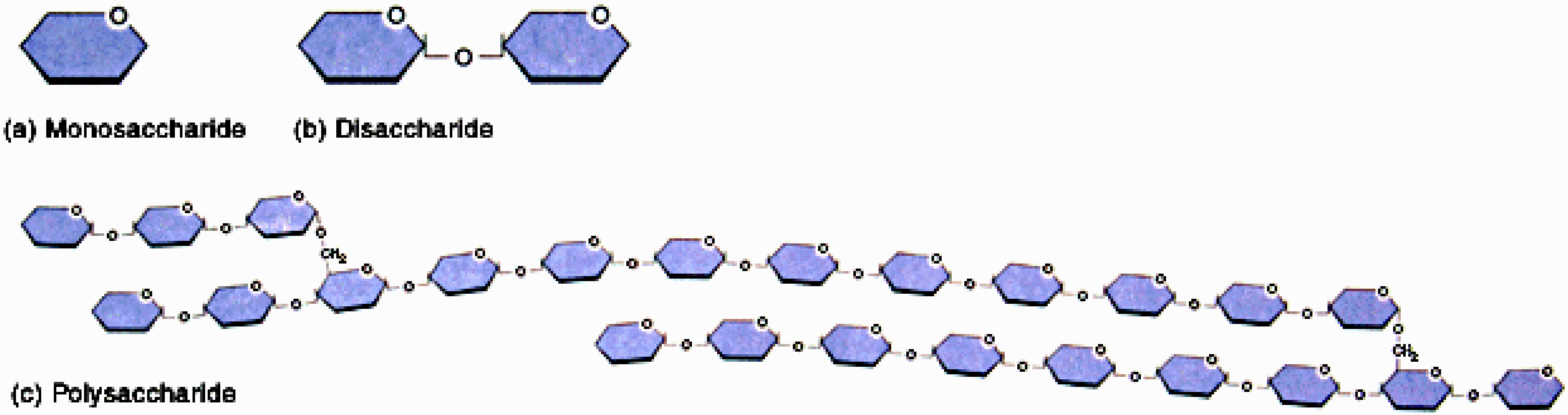
Carbohydrates

- **Polysaccharide**
  - Polysaccharide are the largest carbohydrates and may contain hundreds of monosaccharides. The principal polysaccharide in the human body is ***glycogen***, which is stored in the liver or skeletal muscles.



(c) Portion of a polysaccharide molecule (glycogen)

Monosaccharide Molecule.



Lipids

- ***Lipids***, like carbohydrates, contain carbon, hydrogen, and oxygen; but unlike carbohydrates, they do not have a 2:1 ratio of hydrogen to oxygen.
  - They have fewer polar covalent bonds and thus are mostly insoluble in polar solvents such as water (they are hydrophobic). <u>Table 2.7</u>

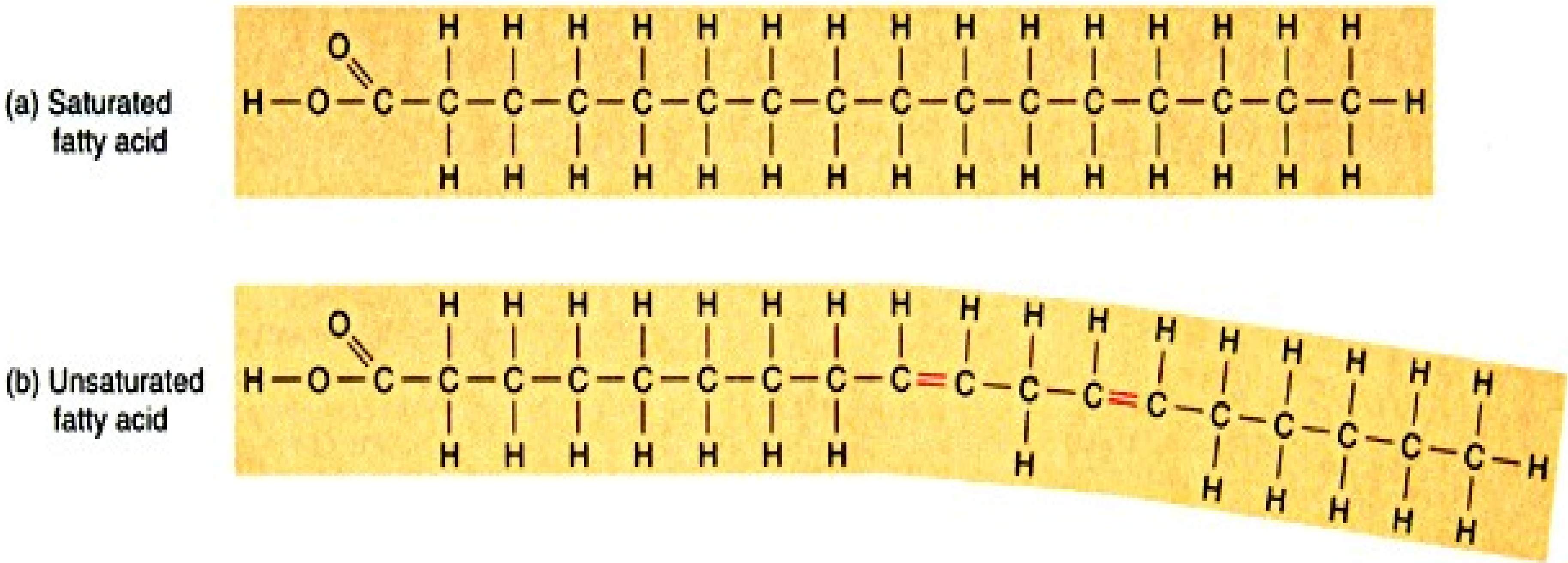
Lipids

- Triglycerides are the most plentiful lipids in the body and provide protection, insulation, and energy (both immediate and stored). At room temperature, triglycerides may be either solid (fats) or liquid (**oils**).
  - Triglycerides provide more than twice as much energy per gram as either carbohydrates or proteins.
  - Triglyceride storage is virtually unlimited.

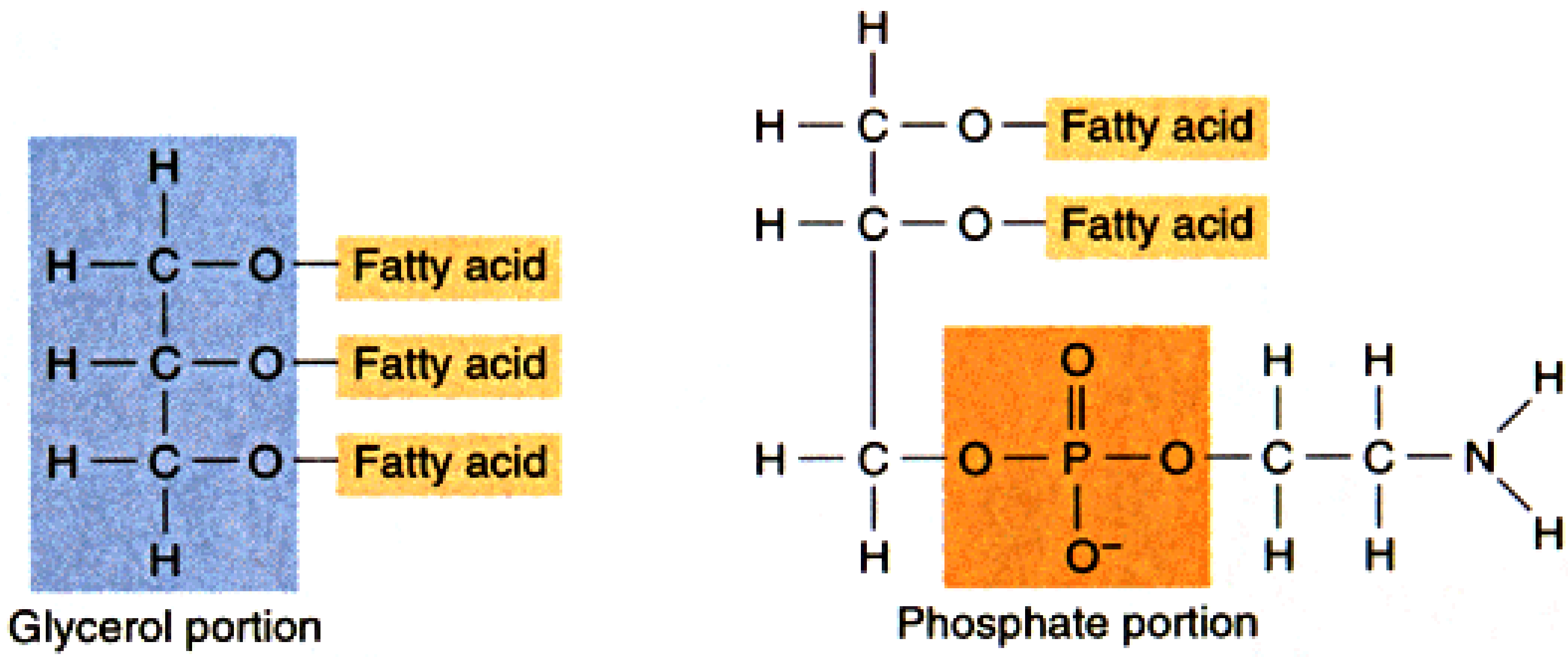
Lipids

- Excess dietary carbohydrates, proteins, fats, and oils will be deposited in adipose tissue as triglycerides.
- Triglycerides are composed of glycerol and fatty acids (Fig.2.17).
- The type of covalent bonds (and by inference, number of hydrogen atoms) found in the fatty acids determines whether a triglyceride is saturated, monounsaturated, or polyunsaturated.

Fatty Acid.



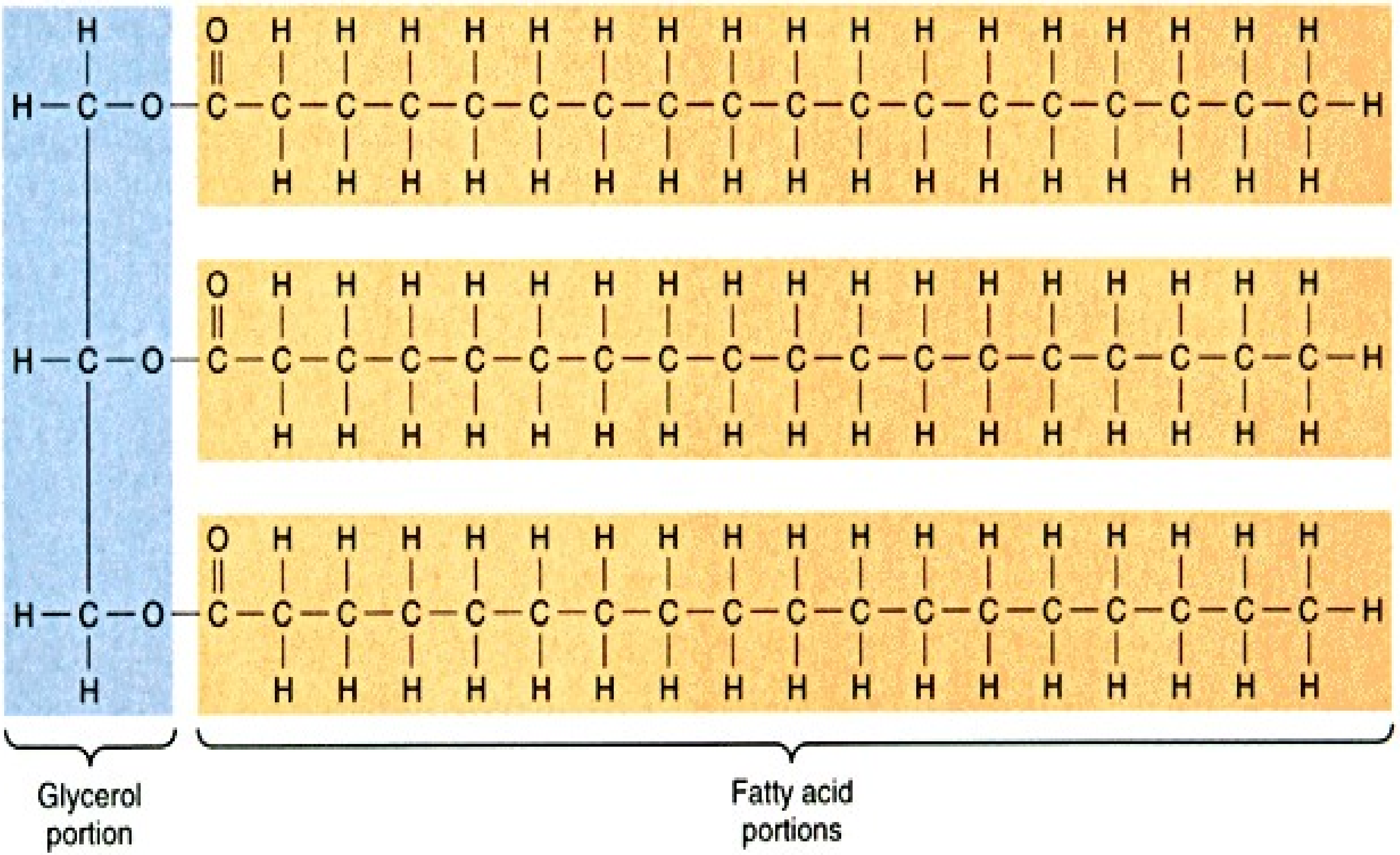
Fat Molecule.

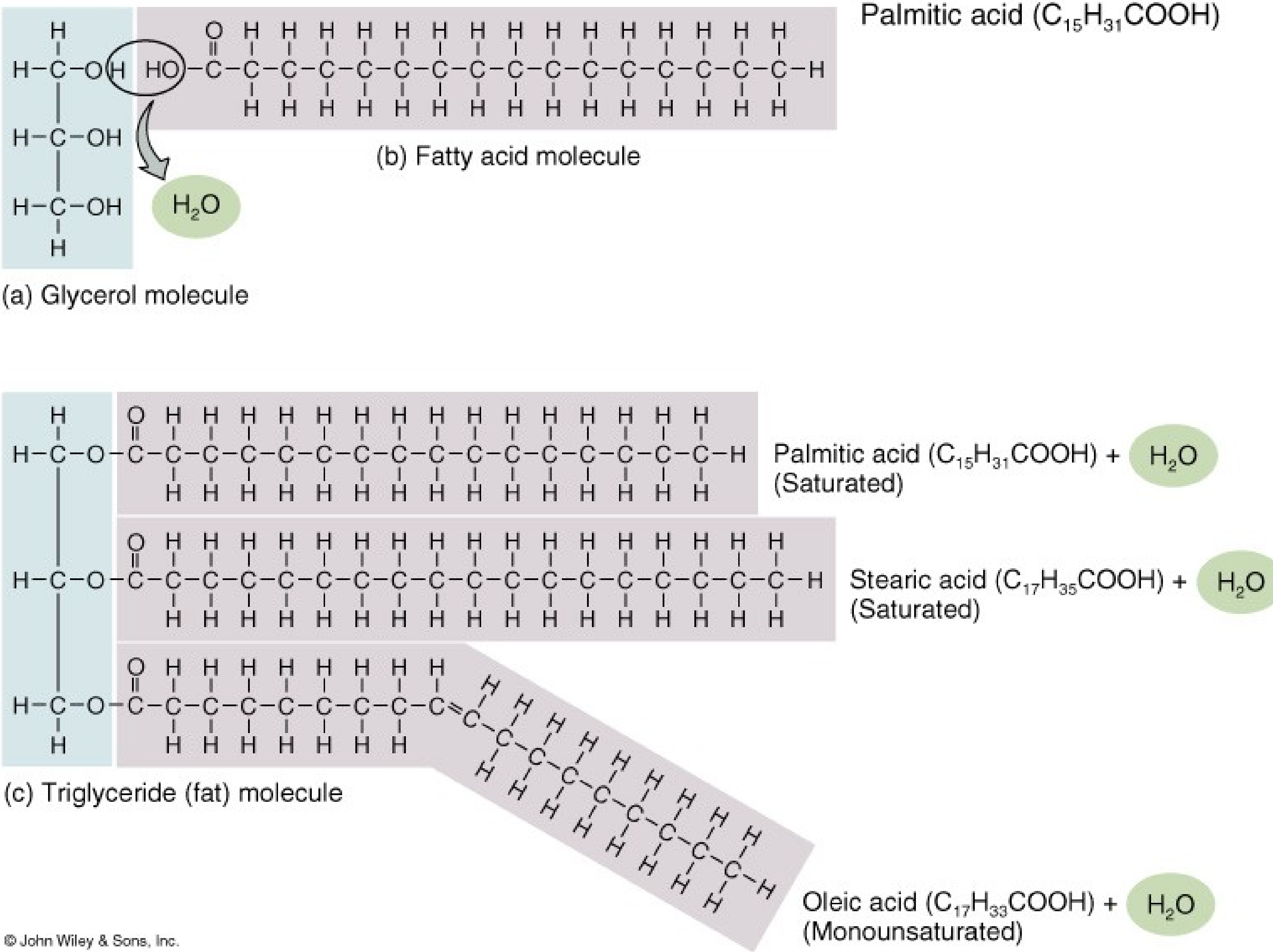


(a) A fat molecule

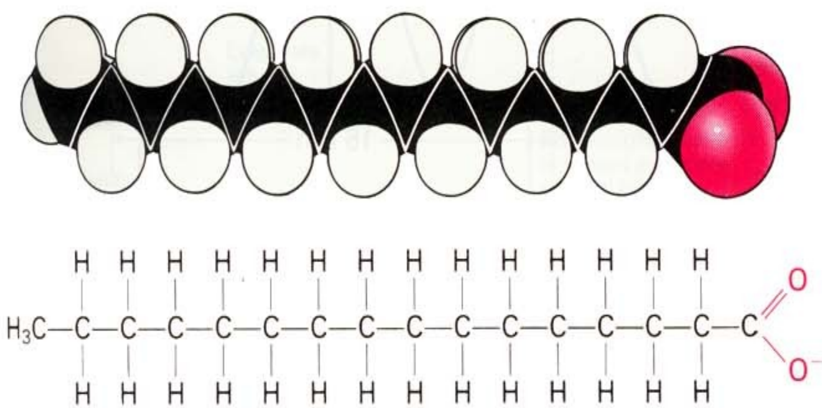
(b) Cephalin (a phospholipid molecule)

Triglyceride Molecule.

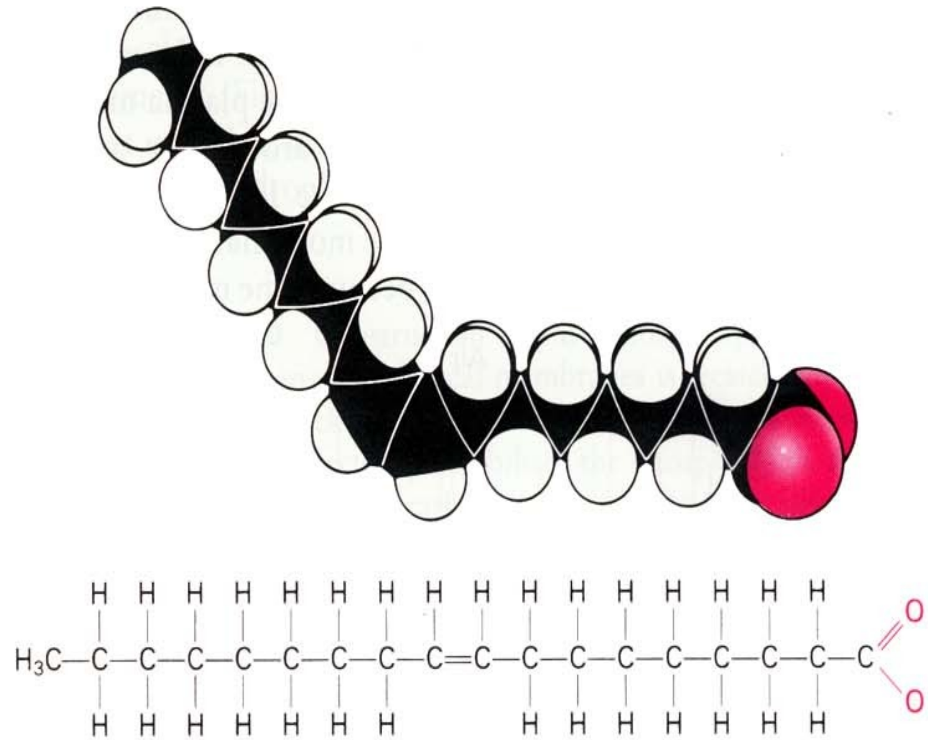




Palmitic acid ($C_{15}H_{31}COOH$)
H_2O
(a) Glycerol molecule
(b) Fatty acid molecule
Palmitic acid ($C_{15}H_{31}COOH$) + H_2O
(Saturated)
Stearic acid ($C_{17}H_{35}COOH$) + H_2O
(Saturated)
Oleic acid ($C_{17}H_{33}COOH$) + H_2O
(Monounsaturated)
(c) Triglyceride (fat) molecule



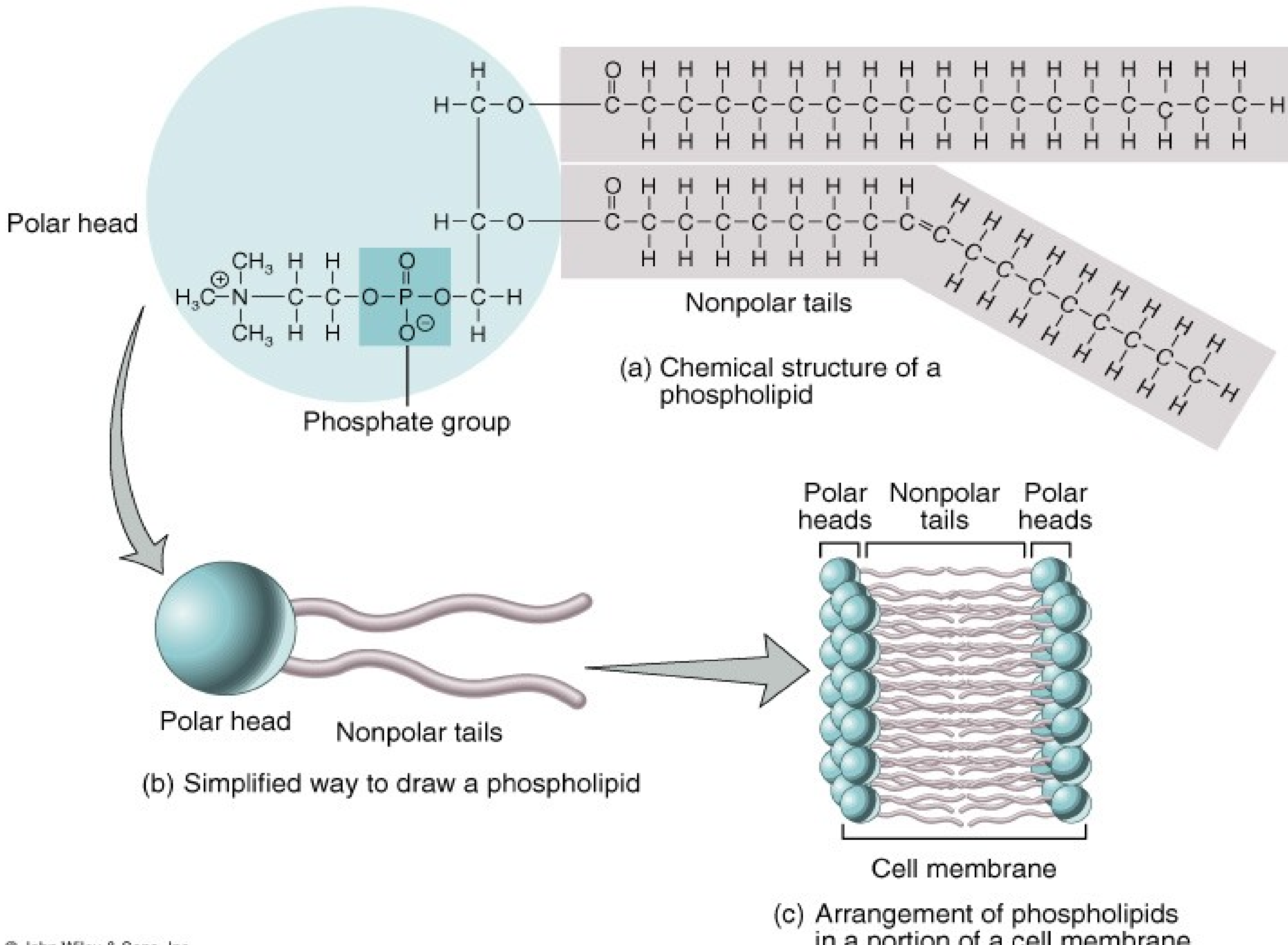
Palmitate
(ionized form of palmitic acid)



Oleate
(ionized form of oleic acid)

Phospholipids

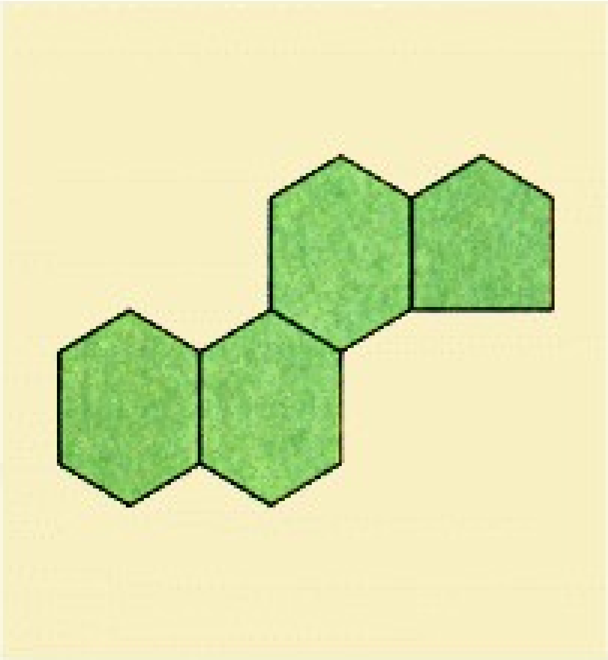
- Are important membrane components.
- They are *amphipathic*, with both polar and nonpolar regions (Fig. 2.18).


Polar head
Phosphate group
Nonpolar tails
(a) Chemical structure of a phospholipid
Polar head
Nonpolar tails
(b) Simplified way to draw a phospholipid
Polar heads
Nonpolar tails
Polar heads
Cell membrane
(c) Arrangement of phospholipids in a portion of a cell membrane

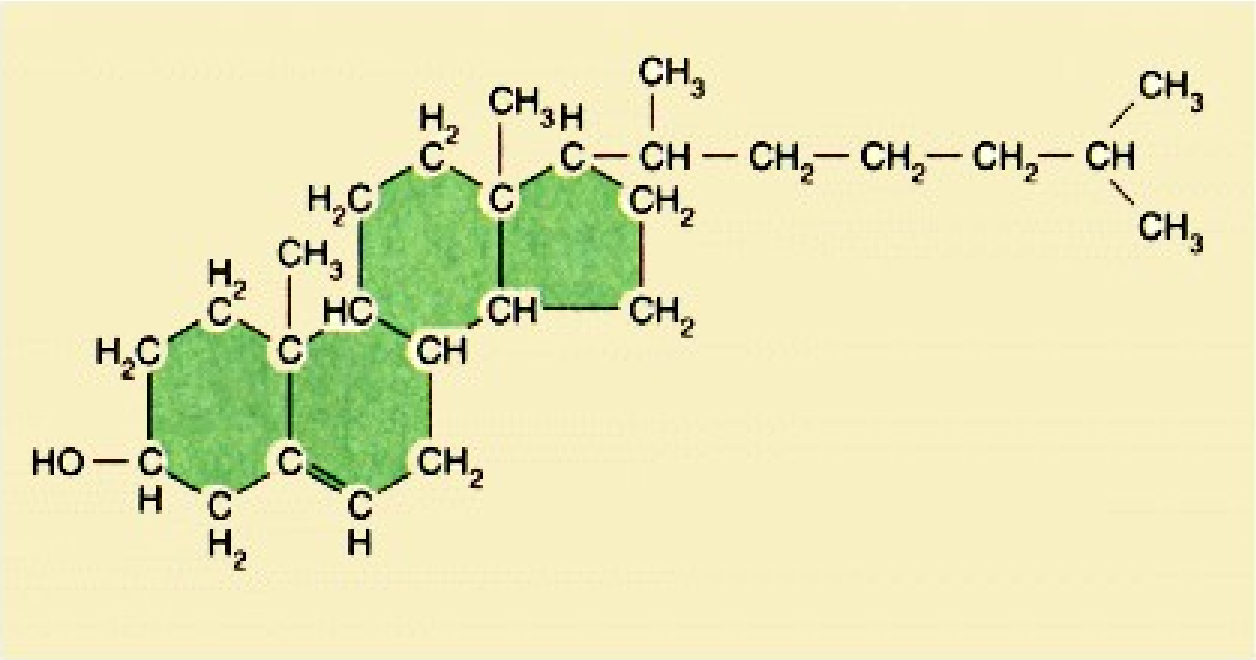
Steroids

- *Steroids* have four rings of carbon atoms (Fig. 2.19). Steroids include sex hormones and **cholesterol**, with cholesterol serving as an important component of cell membranes and as starting material for synthesizing other steroids.

Structure of a Steroid.



(a) Structure of a steroid



(b) Cholesterol

Other Lipids

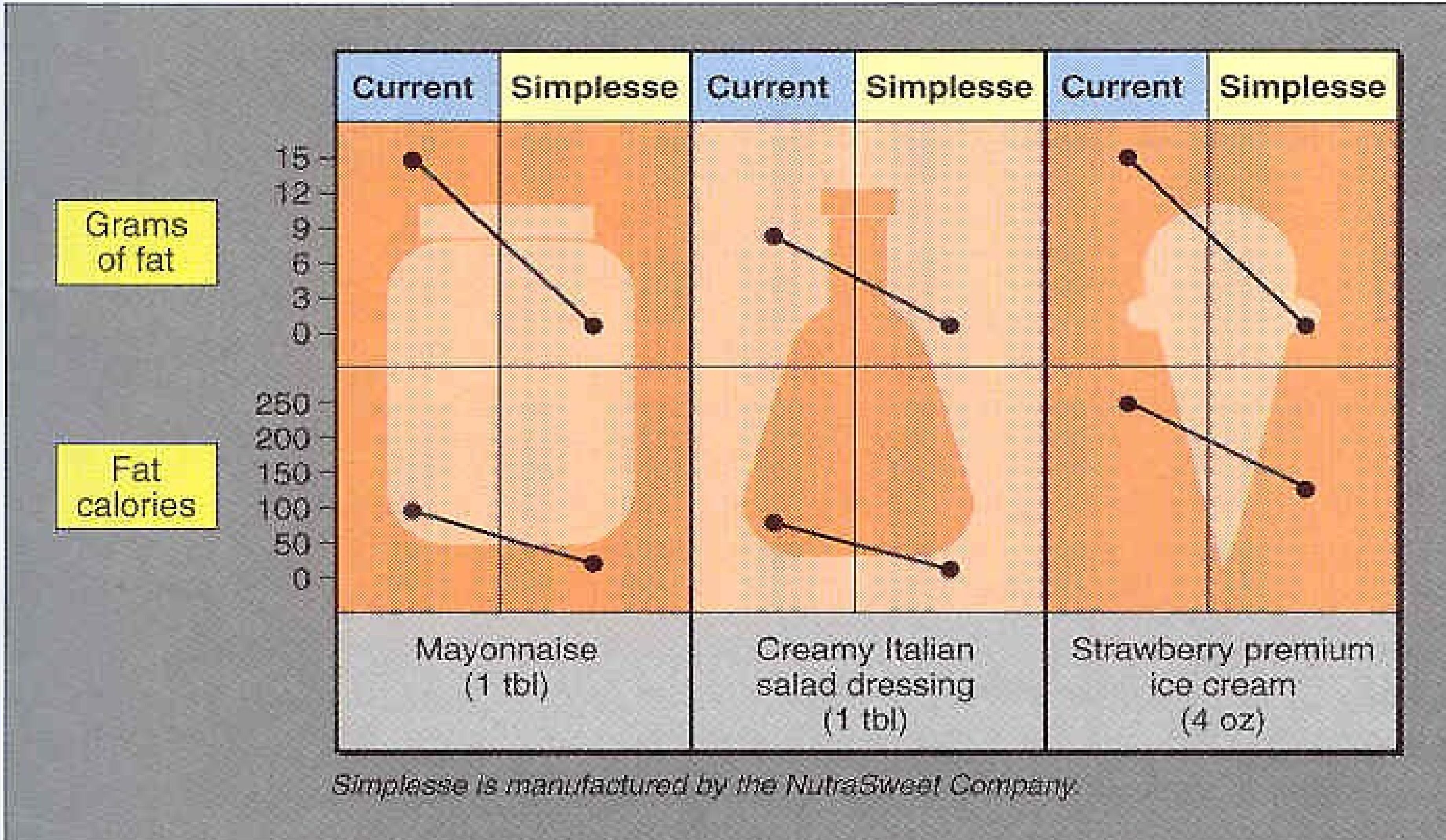
- Prostaglandins modify responses to hormones, contribute to inflammatory responses, prevent stomach ulcers, dilate airways to the lungs, regulate body temperature, and influence blood clots, among other things.
- Leukotrienes participate in allergic and inflammatory responses.
- Body lipids also include fatty acids; fat-soluble vitamins such as beta-carotenes, vitamins D, E, and K; and lipoproteins.

TABLE 4–1. EXAMPLES OF FOODS HIGH AND LOW IN SATURATED FAT, FOODS HIGH IN MONOUNSATURATED FAT, AND THE POLYUNSATURATED TO SATURATED FAT (P/S) RATIO OF COMMON FATS AND OILS

HIGH SATURATED, %		LOW SATURATED, %		HIGH MONOUNSATURATED, %	
Coconut oil	88	Popcorn	0	Olives, black	80
Palm kernal oil	82	Hard candy	0	Olive oil	74
Butter	61	Yogurt, nonfat	2	Almond oil	70
Cream cheese	57	Crackerjacks	3	Canola oil	60
Coconut	56	Milk, skim	4	Almonds, dry	52
Hollandaise sauce	54	Cookies, fig bars	4	Avocados	51
Palm oil	49	Graham crackers	5	Peanut oil	46
Half & half	45	Chicken breast, roasted	6	Cashews, dry roasted	42
Cheese, Velveeta	43	Pancakes	8	Peanut butter	39
Cheese, mozzarella	41	Cottage cheese, 1%	8	Bologna	39
Ice cream, vanilla	38	Milk, chocolate, 1%	9	Beef, cooked	33
Cheesecake	32	Beef, dried	9	Lamb, roasted	32
Chocolate almond bar	29	Chocolate, mints	10	Veal, roasted	26

HIGH POLY-UNSATURATED, %		P/S RATIO, FATS & OILS	
Safflower oil	81	Coconut oil	0.2/1.0
Sunflower oil	73	Palm oil	0.2/1.0
Corn oil	59	Butter	0.1/1.0
Walnuts, dry	51	Olive oil	0.6/1.0
Sunflower seeds	47	Lard	0.3/1.0
Margarine, corn oil	45	Canola oil	5.3/1.0
Canola oil	32	Peanut oil	1.9/1.0
Sesame seeds	31	Soybean oil	2.5/1.0
Pumpkin seeds	31	Sesame oil	3.0/1.0
Tofu	27	Margarine, 100% corn oil	2.5/1.0
Lard	11	Cottonseed oil	2.0/1.0
Butter	6	Mayonnaise	3.7/1.0
Coconut oil	2	Safflower oil	13.3/1.0

Data compiled from the Science and Education Administration, Home and Garden Bulletin 72, Nutritive Value of Foods, Washington, DC, US Government Printing Office, 1985, 1986; Agricultural Research Service, United States Department of Agriculture, Nutritive Value of American Foods in Common Units. Agricultural Handbook No. 456, Washington, DC, US Government Printing Office, 1975.



Current
Simplesse
Current
Simplesse
Current
Simplesse
Grams of fat
15
12
9
6
3
0
Fat calories
250
200
150
100
50
0
Mayonnaise (1 tbl)
Creamy Italian salad dressing (1 tbl)
Strawberry premium ice cream (4 oz)
Simplesse is manufactured by the NutraSweet Company.

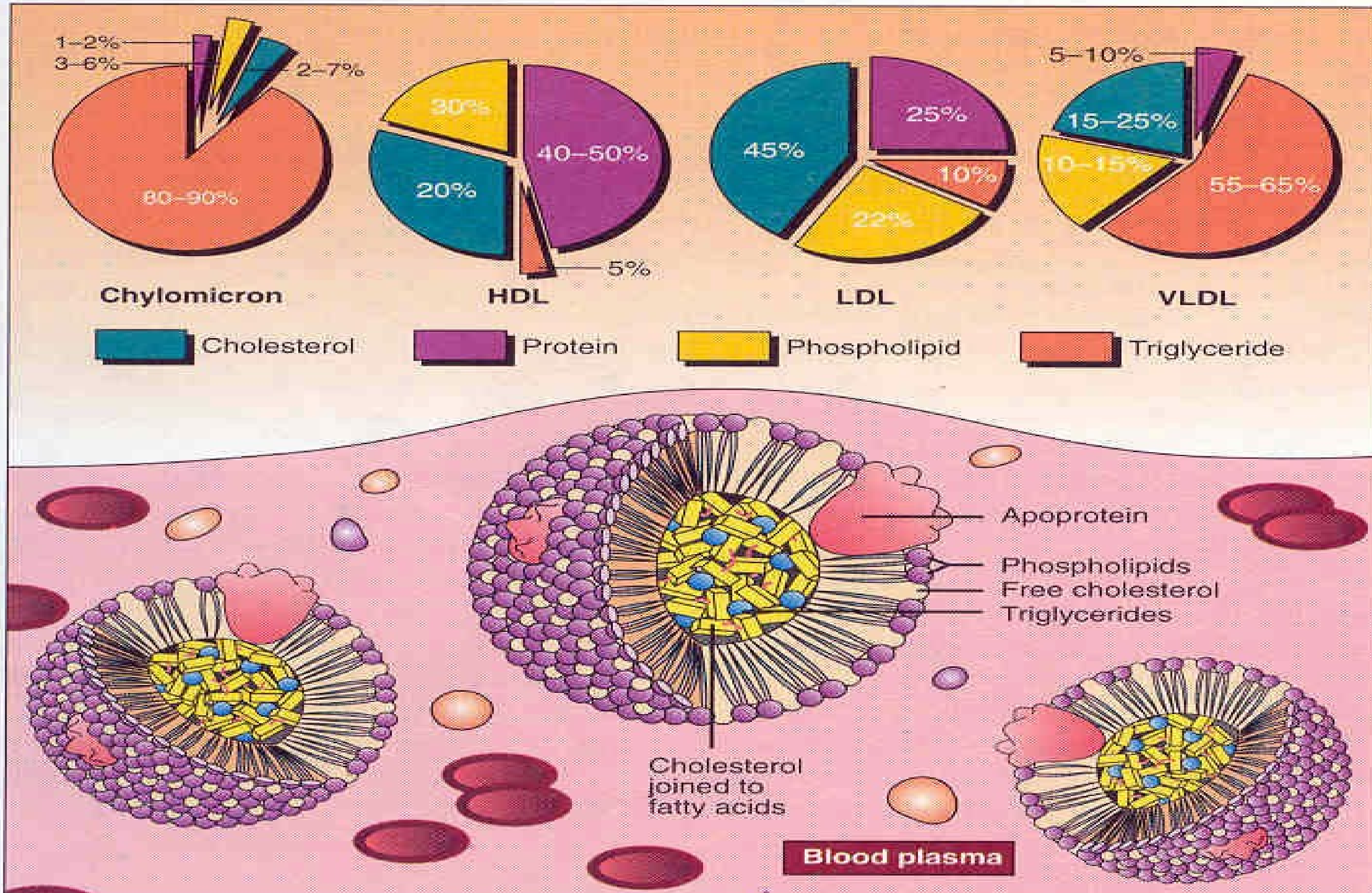


FIG. 4–3. Structural details and composition of lipoproteins. Free cholesterol and triglyceride are carried in the chylomicron. The chylomicrons transport the absorbed lipids from the intestines to the cells of the body. The VLDL and LDL subfractions carry fats made in the liver to the cells. The LDL delivers cholesterol to cells, while the HDL transports cholesterol away from cells to the liver.

Proteins

- *Proteins* give structure to the body, regulate processes, provide protection, help muscles to contract, transport substances, and serve as **enzymes** (Table 2.8).
- Proteins are constructed from combinations of **amino acids**.

Amino Acids

- *Amino acids* are joined together in a stepwise fashion with each covalent bond joining one amino acid to the next forming a bond called a ***peptide bond*** (Fig. 2.21).
- Resulting polypeptide chains may contain 10 to more than 2,000 amino acids.

Amino Acids

- Amino acids contain carbon, hydrogen, oxygen and nitrogen (Fig. 2.20).
- Amino acids are the building blocks of proteins an consist of:
  - An amino group ($-NH_2$)
  - A **carboxyl group** (-COOH), and
  - A side chain (R group)

Amino Acid

- A class of simple organic compounds containing carbon, hydrogen, oxygen, nitrogen, and in certain cases sulfur.
- These compounds are the building blocks of proteins.
- They are characterized by the presence of a carboxyl group (COOH) and an amino group (NH_2) attached to the same carbon at the end of the compound.

Amino Acid

- The 20 amino acids commonly found in animals are alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, and valine.

Amino Acid

- More than 100 less common amino acids also occur in biological systems, particularly in plants.
- Every amino acid except glycine can occur as either of two optically active **stereoisomers**, **d** or **L**; the more common isomer in nature is the L-form.

Isomer

- **Isomer**, in chemistry, one of two or more compounds having the same molecular formula but different structures (arrangements of atoms in the molecule).
- Isomers have the same number of atoms of each element in them and the same atomic weight but differ in other properties.

Stereoisomerism

- **Stereoisomerism** occurs when two or more molecules have the same basic arrangement of atoms in their molecules but differ in the way the atoms are arranged in space.

Stereoisomerism

- When plane-polarized light is passed through an optical isomer it is rotated into a different plane of polarization. Optical isomers exhibit this optical activity in varying degrees.
- Optical isomers of a given compound are often identical in all physical properties except the direction in which they rotate light.

Stereoisomerism

- The molecules of optical isomers are asymmetrical.
- The simplest optical isomers have a single "asymmetrical carbon atom" in their molecules.
- An asymmetrical carbon atom has four different atoms or radicals bonded to it, arranged approximately at the corners of a tetrahedron centered on the carbon atom.

Stereoisomerism

- For example, there are two optical isomers of lactic acid:
-

d-*lactic acid*		*l-lactic acid*

$$\begin{array}{ccc}
\text{COOH} & & \text{COOH} \\
| & & | \\
\text{HO--C--H} & \textit{and} & \text{H--C--OH} \\
| & & | \\
CH_3 & & CH_3
\end{array}$$

d-*lactic acid* l-*lactic acid*

Stereoisomerism

- The atom and radical to either side of the carbon atom are visualized as being above the plane of the paper, the central carbon atom in the plane of the paper, and the radicals above and below the central carbon atom below the plane of the paper.

Stereoisomerism

- Thus it is seen that the two molecules are mirror images of each other and, each being asymmetrical, cannot be superposed on each other.
- The *d*- and *l*- prefixes stand for *dextro* (right) and *levo* (left).

Amino Acid

- When the carboxyl carbon atom of one amino acid covalently binds to the amino nitrogen atom of another amino acid with the release of a water molecule, a peptide bond is formed.

Amino Acid

- Amino acids are released in the intestinal tract by the digestion of food proteins and are then carried in the bloodstream to the body cells, where they are used for growth, maintenance, and repair.
- Cellular catabolism breaks amino acids down into smaller fragments.

Amino Acid

- Many of the amino acids necessary in metabolism can be synthesized in the human or animal body when needed; these are called nonessential.
- Others cannot be synthesized in sufficient quantities; these are termed essential and must be provided in the diet.

Amino Acid

- Of the 20 amino acids used in protein synthesis, the **essential amino acids** must be present in the diet because the cells cannot synthesize them in adequate amounts.

DIETARY PROTEINS

- Dietary proteins have high **biological value** when they supply amino acids in the proportions needed for the synthesis of human proteins.
- The biological value of egg albumin is 100 (the highest possible value) because its amino acid content is nearly the same as the average human cells.

DIETARY PROTEINS

- Most meat proteins have a biological value of about **70**.
- Cereals and grains about **40**.
- Plants however are either low in total proteins or high in only a few of the human essential amino acids.

Phenylketonuria (PKU)

- Individuals do not have the enzyme ***phenylalamine hydroxylase*** necessary for this conversion so phenylalanine is converted to phenylpyruvic acid.
- The diet of a person with PKU must contain some tyrosine and must be limited in the amount of phenylalanine or mental retardation will occur.

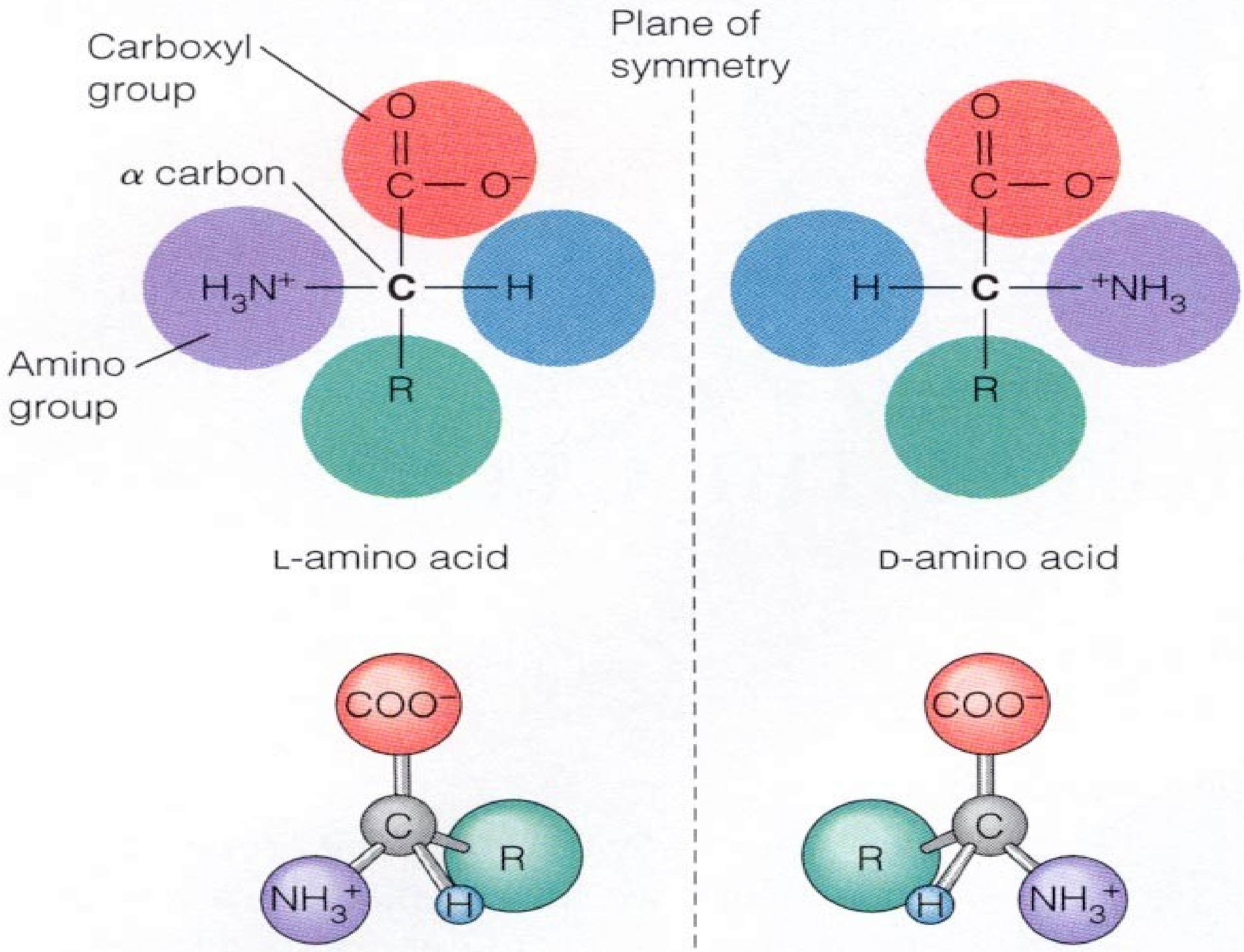


Figure 3-1 The Structure and Stereochemistry of an Amino Acid. Because the α carbon atom is asymmetric in all amino acids except glycine, most amino acids can exist in two isomeric forms, designated L and D and shown here as (top) conventional structural formulas and (bottom) ball-and-stick models. The L and D forms are stereoisomers, with the vertical dashed line as the plane of symmetry. Of the two forms, only L-amino acids are present in proteins.

PROTEIN

- Proteins make up essential parts of tissues and guide chemical reactions in living things.
- They are made of **20 different building blocks called amino acids.**
- The DNA sequence of a gene determines the amino acid sequence of the protein that gene encodes.
- The amino acid sequence of the protein is, in turn, responsible for the **protein's shape and function.**

Proteins

- Resulting polypeptide chains may contain 10 to more than 2,000 amino acids.
- Levels of Structural Organization
  - Levels of structural organization include primary, secondary,tertiary, and quaternary structures. The resulting shape of the protein greatly influences its ability to recognize and bind to other molecules.
  - *Denaturation* of a protein by a hostile environment causes loss of its characteristic shape and function.

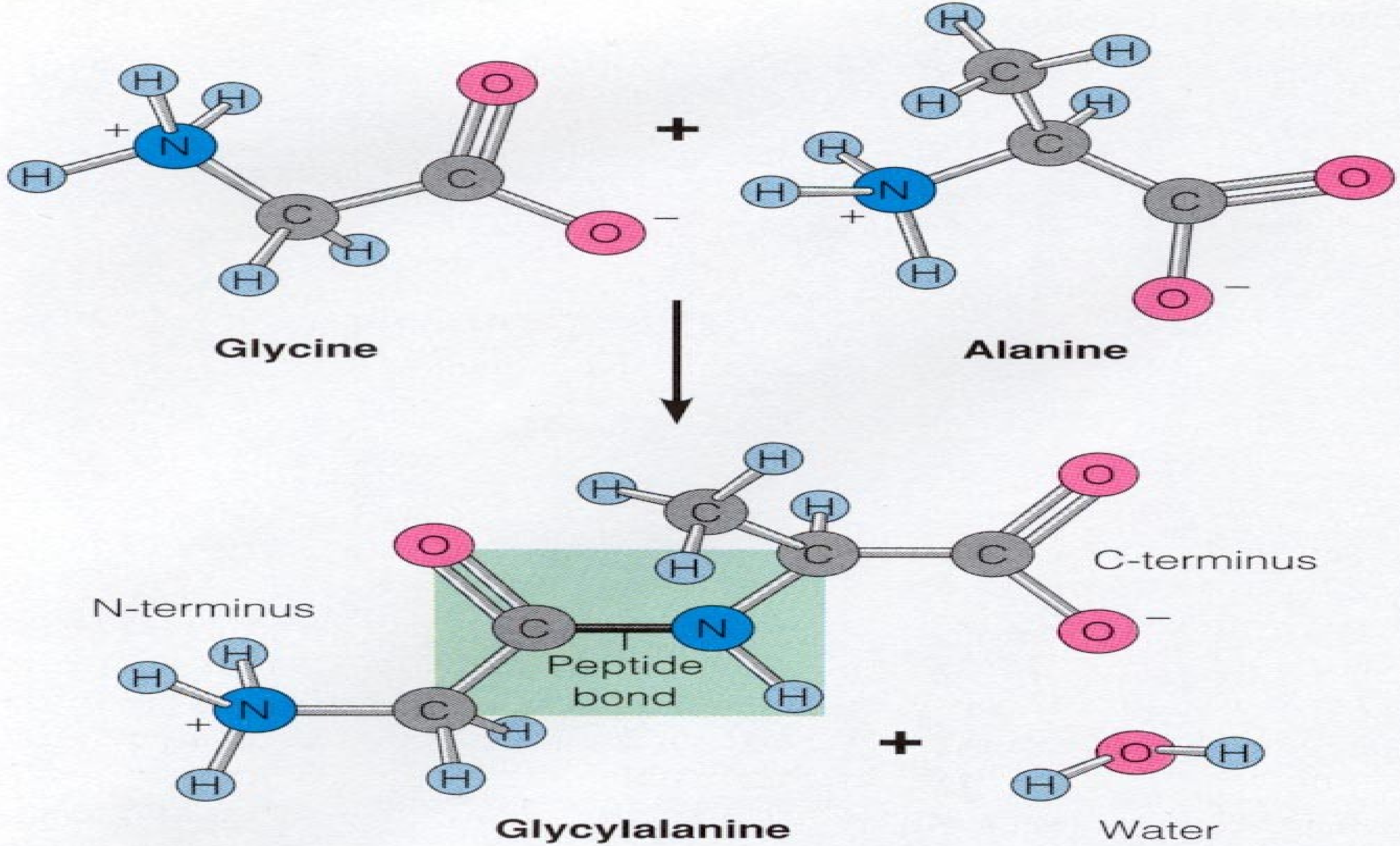
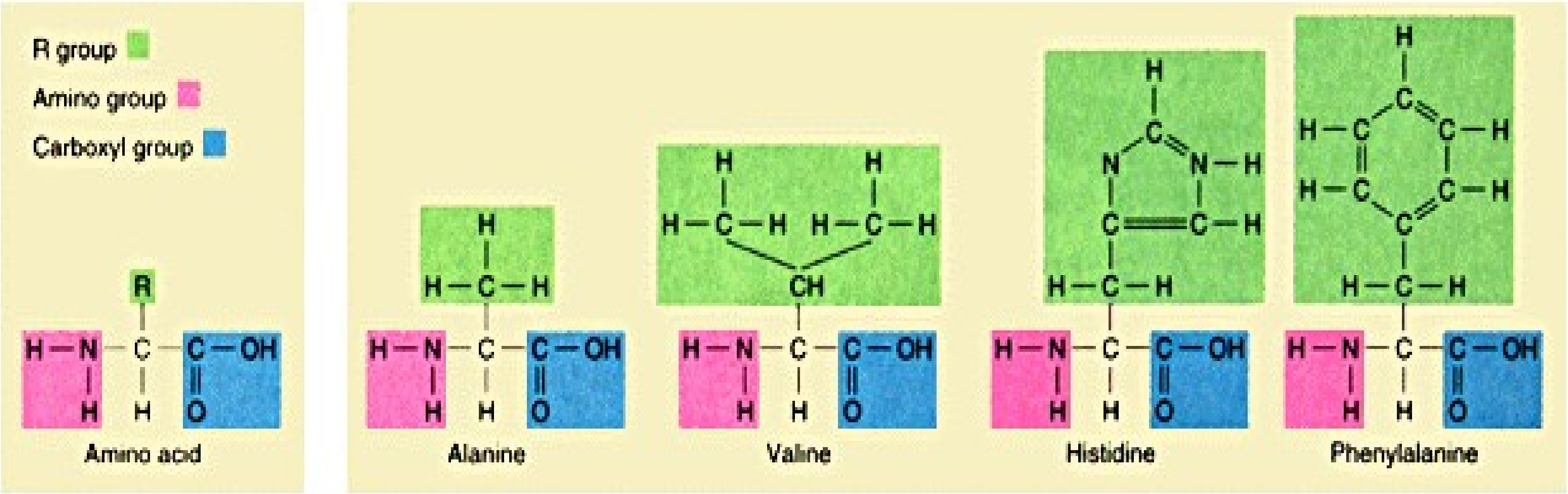


Figure 3-3 Peptide Bond Formation. Successive amino acids in a polypeptide are linked to one another by peptide bonds between the carboxyl group of one amino acid and the amino group of the next. Shown here is the formation of a peptide bond between the amino acids glycine and alanine.

Structure of an Amino Acid.



(a) (b)

Amino Acids

- Amino acids form thousands of different proteins, and are not only the **units** from which proteins are formed, but are also the **end products** of protein digestion.

Amino Acids

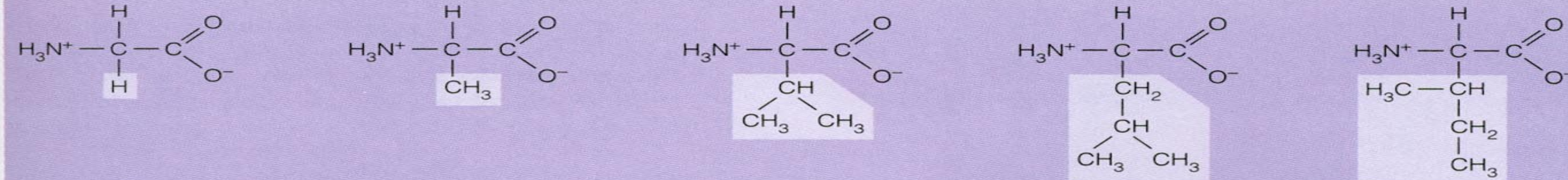
- There are 22 known amino acids which 20 are utilized by the body to build proteins, 8 of which are called, because the ***essential amino acids*** **CANNOT** be manufactured by the human body and must be obtained from food or supplements.

Essential Amino Acids

1. Leucine
2. Lysine
3. Methionine
4. Phenylalanine
5. Threonine
6. Tryptophan
7. Valine
8. Losleucine

Amino Acid	Three-Letter Abbreviation	One-Letter Abbreviation
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartate	Asp	D
Cysteine	Cys	S
Glutamate	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
→ Isoleucine	Ile	I
→ Leucine	Leu	L
→ Lysine	Lys	K
→ Methionine	Met	M
→ Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
→ Threonine	Thr	T
Tyrosine	Tyr	Y
→ Tryptophan	Trp	W
→ Valine	Val	V

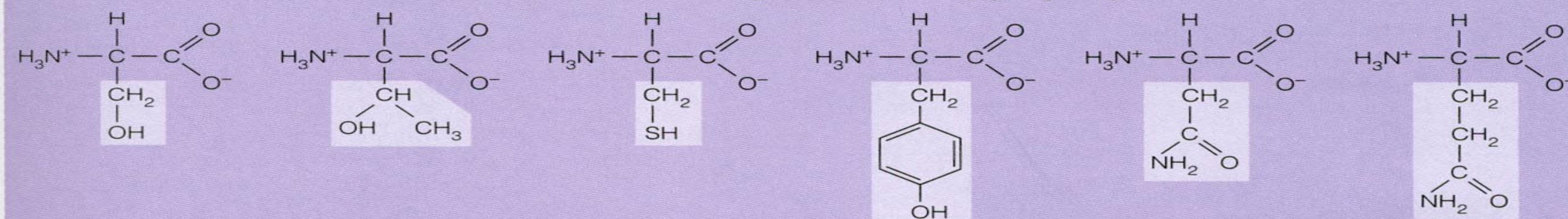
Group A: Nonpolar Amino Acids (Hydrophobic)



Glycine | Alanine | Valine | Leucine | Isoleucine

Methionine | Phenylalanine | Tryptophan | Proline

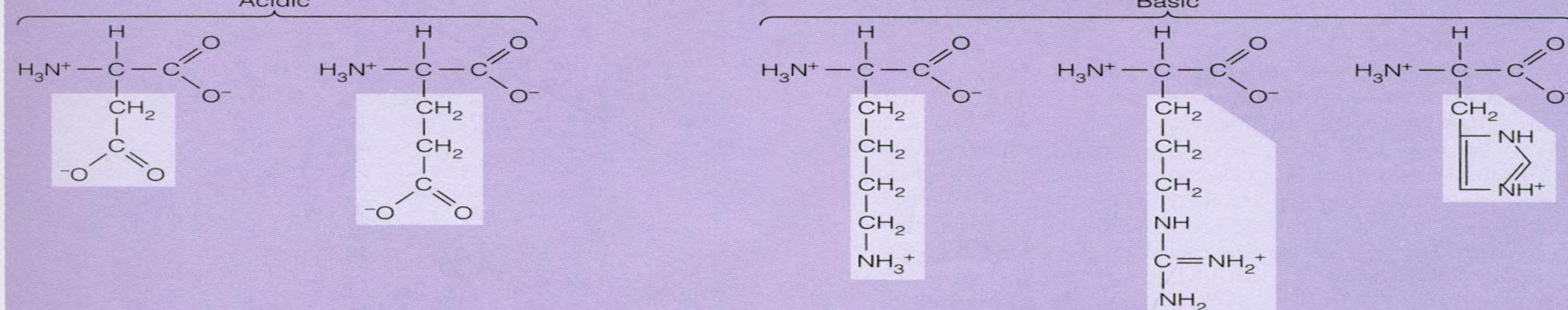
Group B: Polar, Uncharged Amino Acids (Hydrophilic)



Serine | Threonine | Cysteine | Tyrosine | Asparagine | Glutamine

Group C: Polar, Charged Amino Acids (Hydrophilic)

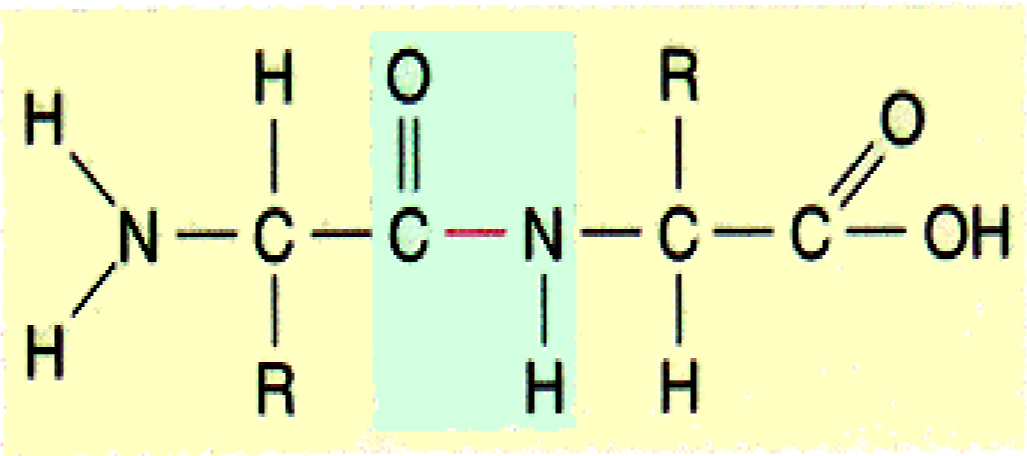
Acidic | Basic



Aspartate | Glutamate | Lysine | Arginine | Histidine

Proteins Levels of Structural Organization

- Levels of structural organization include
  1. Primary,
  2. Secondary,
  3. Tertiary, and
  4. Quaternary structures.
- The resulting shape of the protein greatly influences its ability to function, so that it can to recognize and bind to other molecules.

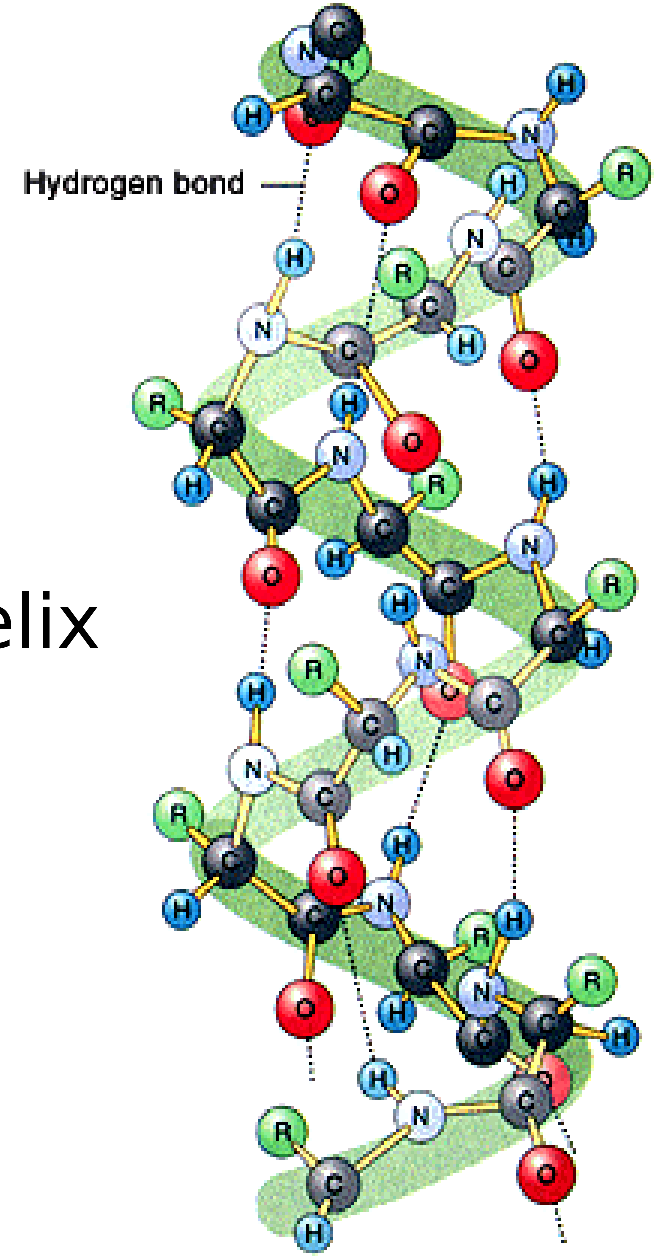


(a)

Primary Structure of a Protein.
Figure 2.16

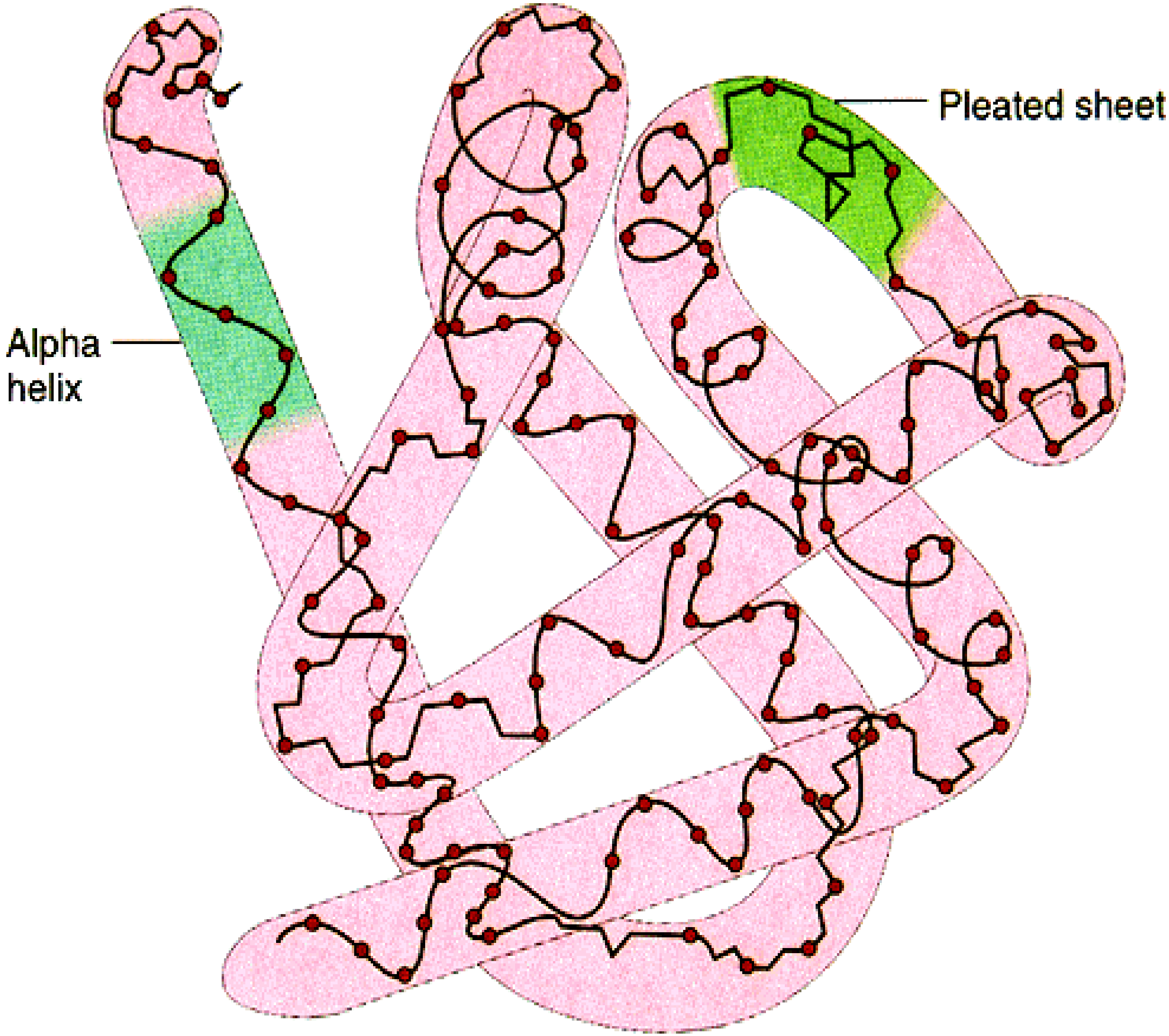
Secondary Structure of a Protein.

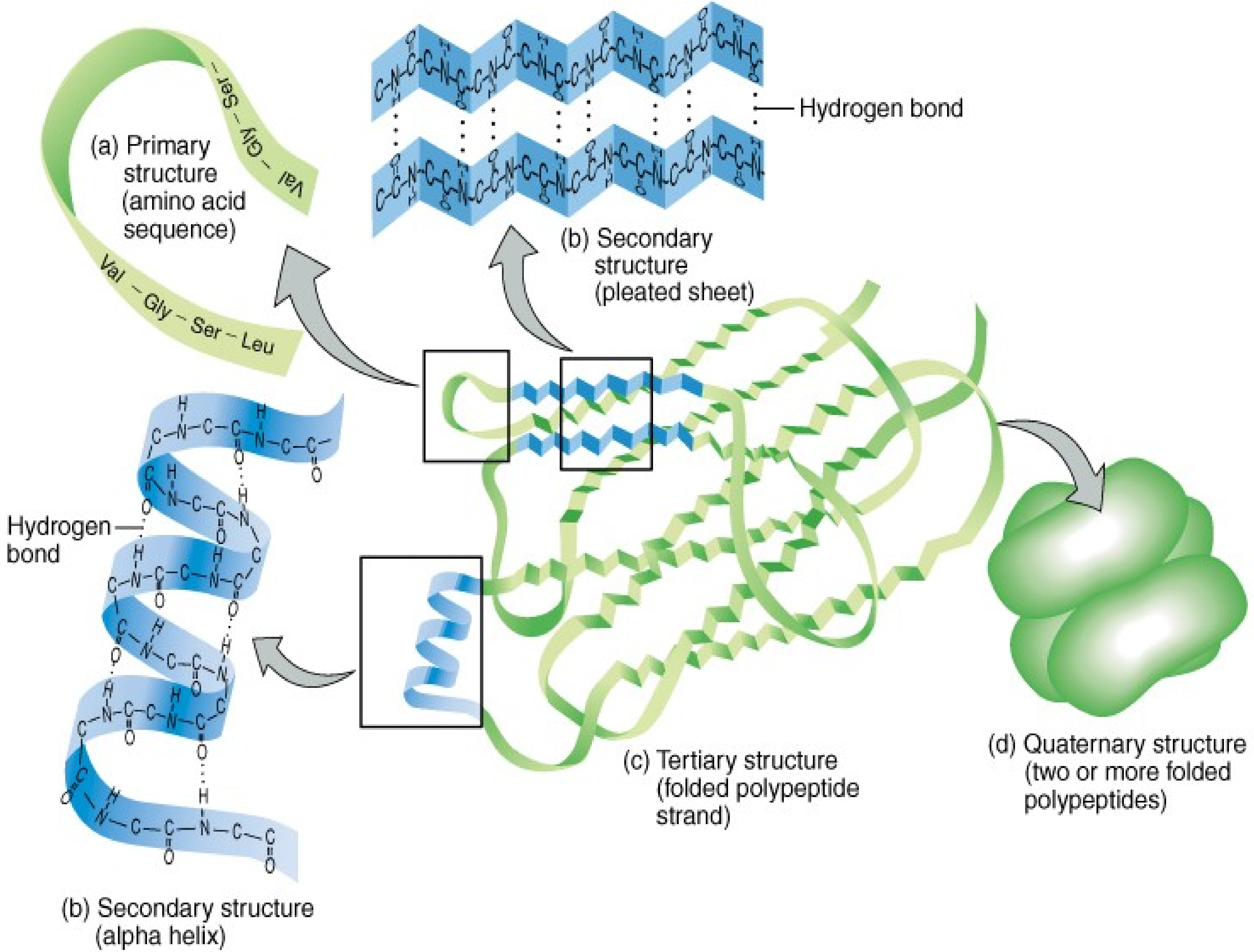
Alpha Helix

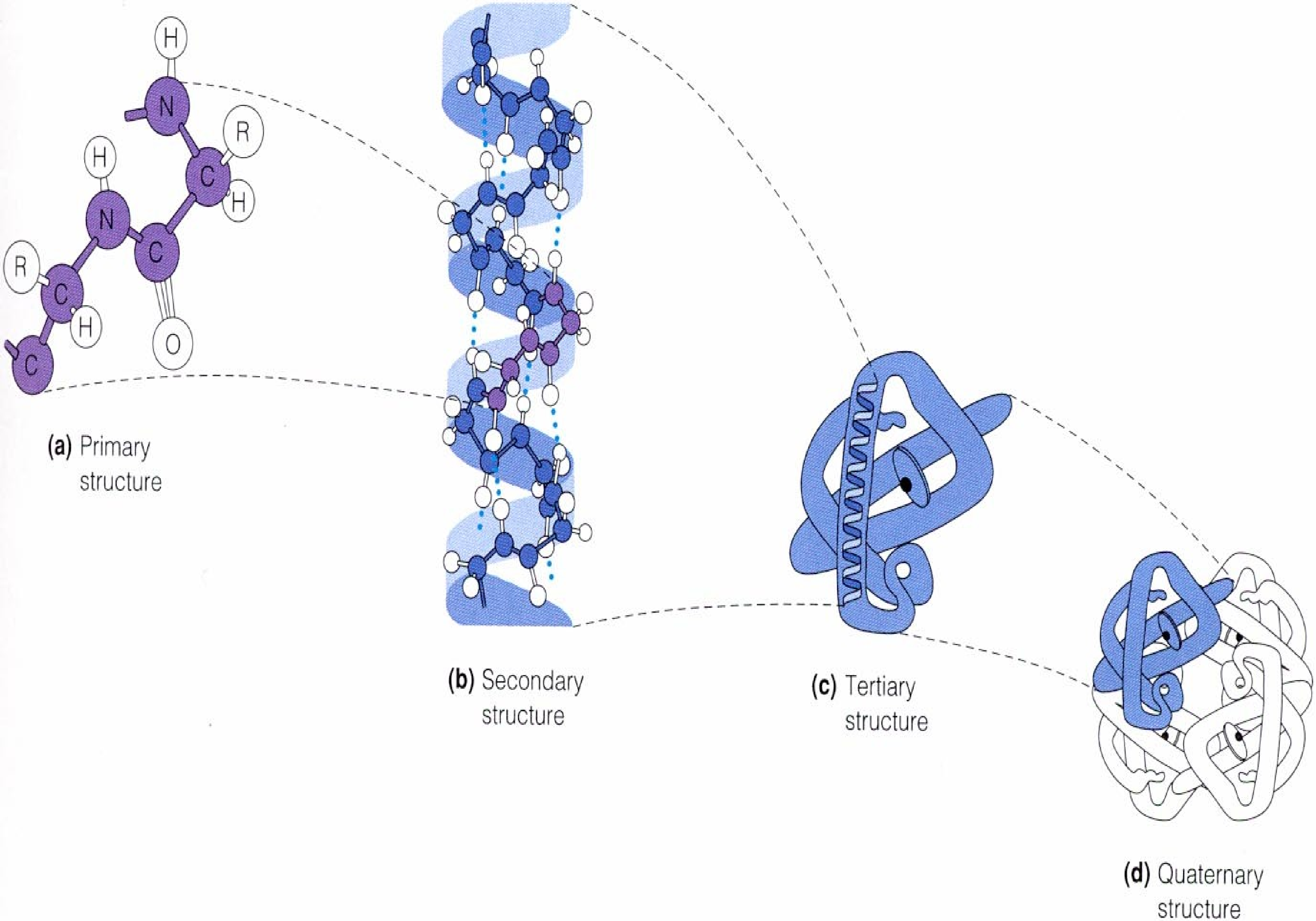


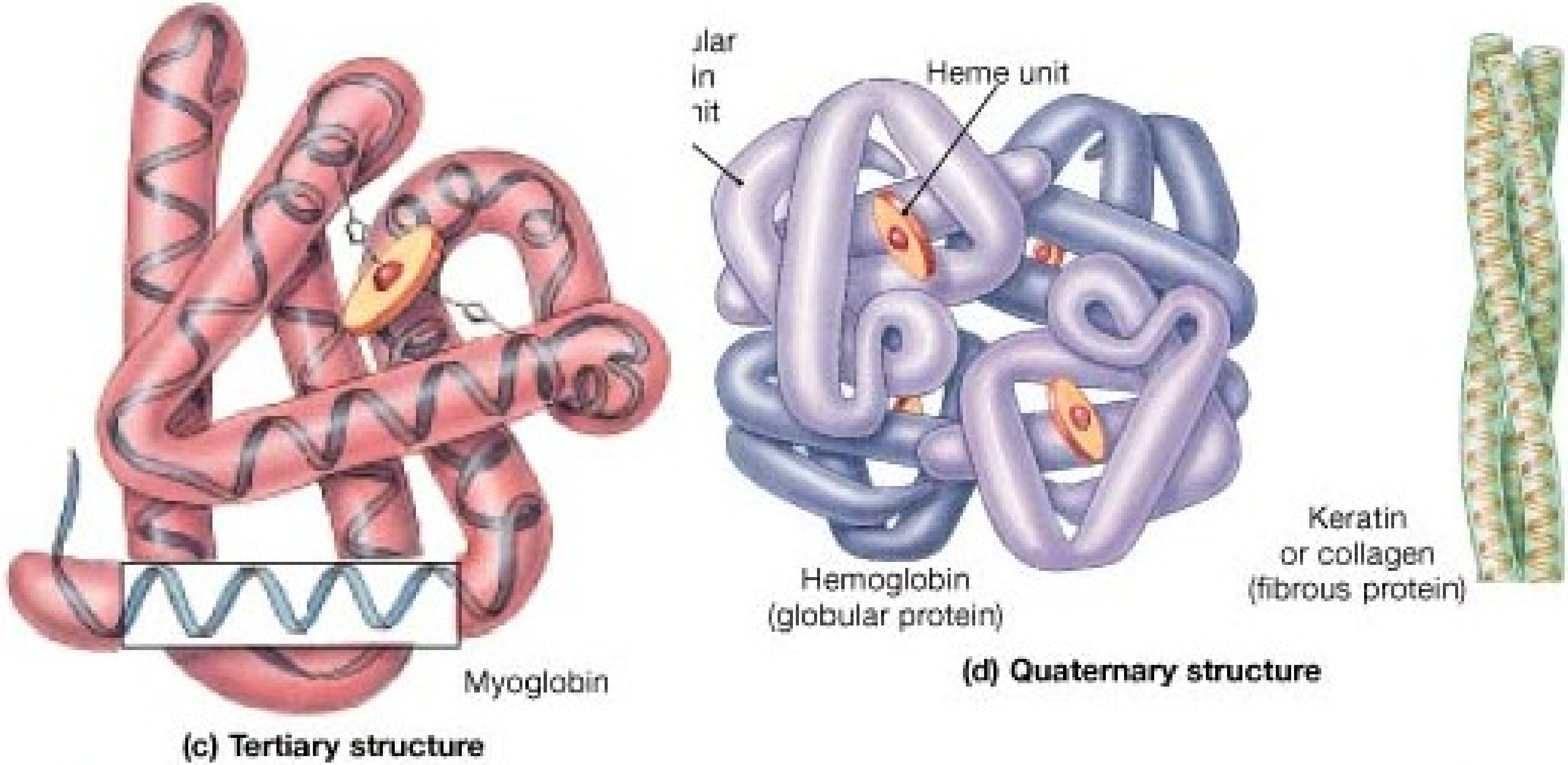
Portion of a protein molecule

Tertiary Structure of a Protein.




(a) Primary structure (amino acid sequence)
Val – Gly – Ser –
Val – Gly – Ser – Leu
(b) Secondary structure (pleated sheet)
Hydrogen bond
Hydrogen bond
(b) Secondary structure (alpha helix)
(c) Tertiary structure (folded polypeptide strand)
(d) Quaternary structure (two or more folded polypeptides)


H
N
R
H
C
H
N
C
R
C
H
O
C
(a) Primary structure
(b) Secondary structure
(c) Tertiary structure
(d) Quaternary structure



• ***FIGURE 2-18*** **Protein Structure.** **(c)** The tertiary structure is the coiling and folding of a polypeptide. This is the structure of myoglobin, a globular protein involved in the storage of oxygen in muscle tissue. Within the cylindrical segments, the polypeptide chain is arranged in an alpha-helix. **(d)** The quaternary structure develops when separate polypeptide subunits interact to form a larger molecule. A single hemoglobin molecule contains four globular subunits, each structurally similar to myoglobin. Hemoglobin transports oxygen in the blood; the oxygen binds reversibly to the heme units. In keratin and collagen, three fibrous subunits intertwine. Keratin is a tough, water-resistant protein found in skin, hair, and nails. Collagen is the principal extracellular protein in most organs.

Proteins Levels of Structural Organization

- *Denaturation* of a protein by a hostile environment causes loss of its characteristic shape and function.

VITAMINS

Vitamins

- A group of organic substances that are required in the diet of humans and animals for normal growth, maintenance of life, and normal reproduction.
- They act as **catalysts**; very often either the **vitamins** themselves are **coenzymes**, or they form integral parts of coenzymes.

Vitamins

- A substance that functions as a vitamin for one species does not necessarily function as a vitamin for another species.
- The vitamins differ in structure, and there is no chemical grouping common to them all.
- The chemical structures of the vitamins are all known, and all of them have been synthesized; the vitamins in foods are identical to the synthetic ones.

Vitamins

- Two types of vitamins are **fat** soluble and **water** soluble;
- **Vitamin E** (Tocopherols) is a fat soluble and stored in the liver, fatty tissues, heart, muscles, testes, uterus, blood, adrenal and pituitary glands

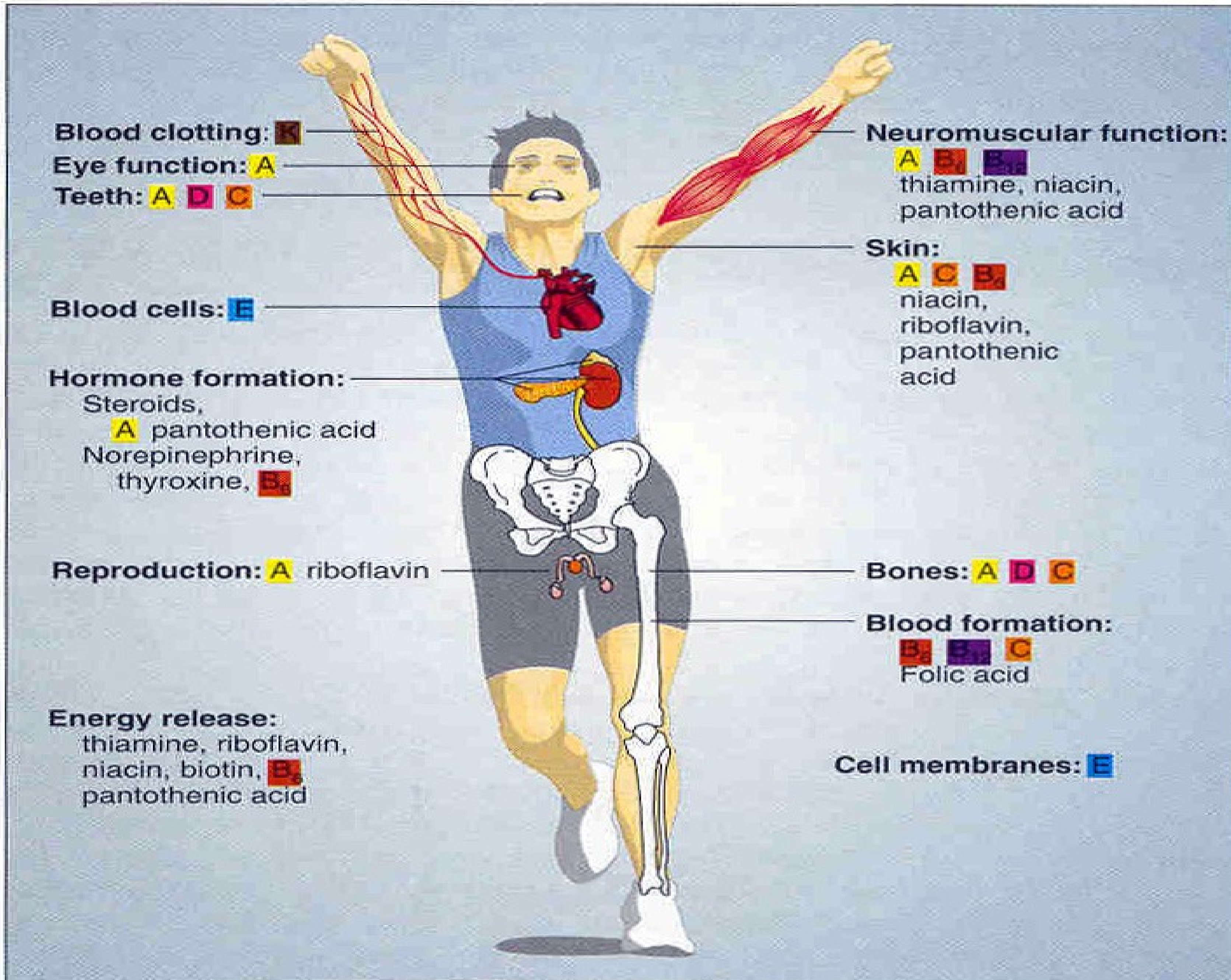
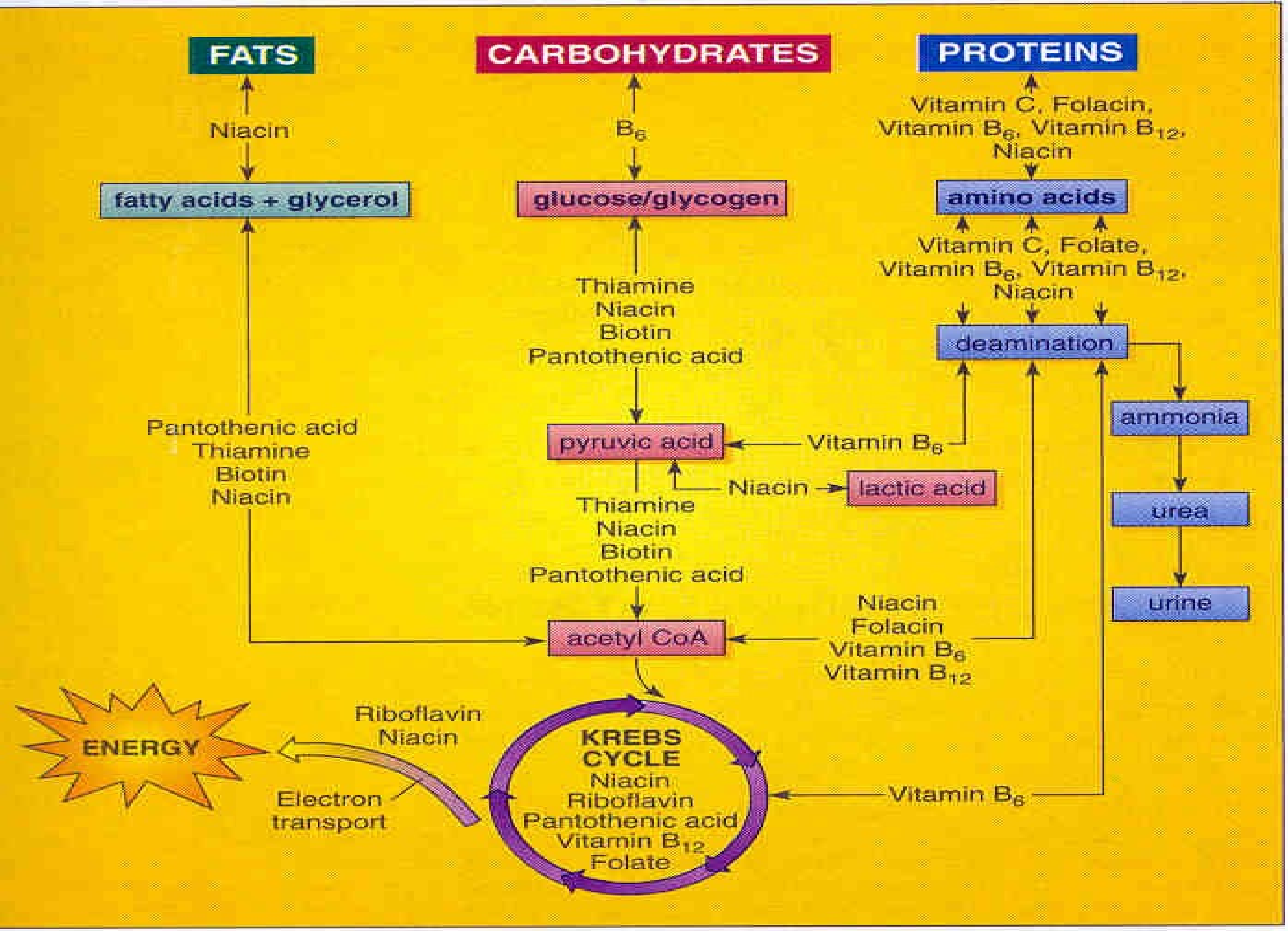


FIG. 6–1. Biologic functions of vitamins in the body.



IG. 6–2. General schema for the role of water-soluble vitamins in food metabolism.

Vitamin A

- Vitamin A (retinol), a fat-soluble lipid, is either derived directly from animal foods such as liver, egg yolks, cream, or butter or is derived from beta-carotene, a pigment that occurs in leafy green vegetables and in yellow fruits and vegetables.

Vitamin A

- Vitamin A is essential to skeletal growth, normal reproductive function, and the health of the skin and mucous membranes.
- One form, retinal, is a component of visual purple, a photoreceptor pigment in the retina of the eye (see vision).

Vitamin A

- In addition, beta-carotene, like other carotenoids, is now recognized as an important **antioxidant**.
- A <u>deficiency of vitamin A</u> can cause retarded skeletal growth, night blindness, various abnormalities of the skin and linings of the genitourinary system and gastrointestinal tract, and, in children, susceptibility to serious infection.

Vitamin A

- The eye disorders that result from a deficiency of vitamin A can lead to permanent blindness. Severe deficiency can cause death.
- As with the other fat-soluble vitamins, conditions that lead to an inability to absorb fats, such as obstruction of bile flow or excessive use of mineral oil, can produce a deficiency state.

Vitamin A

- **Overconsumption** of vitamin A can cause irritability, painful joints, growth retardation, liver and spleen enlargement, hair loss, and birth defects.
- The National Research Council recommended daily dietary allowance for adults is 1,000 micrograms (retinol equivalents) for men and 800 micrograms for women.

Vitamin B Complex

- Commonly grouped as the vitamin B complex are eight water-soluble vitamins.
- ***Thiamine***
  - Thiamine (vitamin B_1 or antiberiberi factor) is a necessary ingredient for the biosynthesis of the coenzyme thiamine pyrophosphate; in this latter form it plays an important role in carbohydrate metabolism.

Thiamine

- Good sources are yeast, whole grains, lean pork, nuts, legumes, and thiamine-enriched cereal products.
- This vitamin is a factor in the maintenance of appetite, normal intestinal function, and in the health of the cardiovascular and nervous systems.

Thiamine

- A deficiency of the vitamin may lead to **beriberi**; the disease was first shown to result from a dietary deficiency by
- The recommended dietary allowance for adults is 1.2 to 1.4 mg for men and 1.0 to 1.1 mg for women.

Riboflavin

- Riboflavin (vitamin B_2 or lactoflavin) is used to synthesize two coenzymes that are associated with several of the respiratory enzymes of plants and animals (including humans) and is therefore important in biochemical oxidations and reductions.

Riboflavin

- Deficiency leads to fissures in the corners of the mouth, inflammation of the tongue showing a reddish purple coloration, skin disease, and often severe irritation of the eyes.
- The recommended dietary allowance for adults is 1.4 to 1.7 mg for men and 1.2 to 1.3 mg for women.

Riboflavin

- Riboflavin is widely distributed in plant and animal tissues; milk, organ meats, and enriched cereal products are good sources.

Niacin

- The B vitamins niacin (nicotinic acid) and niacinamide (nicotinamide) are commonly known as preventives of **pellagra**, which in 1912 was shown by American medical researcher Joseph Goldberger to result from a dietary deficiency.
- Niacin was first synthesized in 1867.

Niacin

- The amino acid **tryptophan** is the precursor of niacin.
- Niacin and niacinamide function in the biochemistry of humans as components of the two coenzymes nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP);

Niacin

- ***Niacin*** - operates in many enzyme-catalyzed oxidation and reduction reactions.
- The deficiency state in humans causes skin disease, diarrhea, dementia, and ultimately death.
- Lean meats, peanuts and other legumes, and whole-grain or enriched bread and cereal products are among the best sources of niacin.

Niacin

- The recommended daily dietary allowance for adults is 16 to 19 mg niacin equivalents (60 mg of dietary tryptophan to 1 mg of niacin) for men and 13 to 14 mg for women.

Vitamin B_6 Group

- ***Vitamin B_6 Group -*** Pyridoxine, pyridoxal, and pyridoxamine make up the vitamin B_6 group.
- They all combine with phosphorus in the body to form the coenzyme pyridoxal phosphate, which is necessary in the metabolism of amino acids, glucose, and fatty acids.

Vitamin B_6 Group

- The best sources of B_6 vitamins are liver and other organ meats, corn, whole-grain cereal, and seeds.
- Deficiency can result in central nervous system disturbances (e.g., convulsions in infants) due to the role of B_6 in **serotonin** and gamma-aminobutyric acid synthesis.

Vitamin B_6 Group

- More generally the effects of deficiency include inadequate growth or weight loss and anemia due to the role of B_6 in the manufacture of **hemoglobin**.
- The recommended dietary allowance for adults is 2.0 to 2.2 mg for men and 2 mg for women.

Vitamin B_6 Group

- Additional doses are required in pregnancy and by those taking oral contraceptives and severe nerve damage has been reported from megadoses.

Pantothenic Acid

- **Pantothenic acid**, another B vitamin, is present in perhaps all animal and plant tissues, as well as in many microorganisms.
- Good sources of it include liver, kidney, eggs, and dairy products.

Pantothenic Acid

- ***Pantothenic Acid***
- It is a component of the important substance coenzyme A, which is involved in the metabolism of many biochemical substances including fatty acids, steroids, phospholipids, heme, amino acids, and carbohydrates.
- The adrenal gland is an important site of pantothenic acid activity.

Pantothenic Acid

- ***Pantothenic Acid***
- There is no known naturally occurring deficiency state and no known toxicity to pantothenic acid.
- The estimated safe and adequate daily intake for adults is 4 to 7 mg.

Biotin

- Biotin is a B vitamin that functions as a coenzyme in the metabolism of carbohydrates, fats, and amino acids.
- Although it is vitally necessary to the body, only exceedingly small quantities are needed, and since biotin is synthesized by intestinal bacteria, naturally occurring biotin deficiency disease is virtually unknown.

Biotin

- The disease state can be produced artificially by including large quantities of raw egg white in the diet; the whites contain avidin, a biotin antagonist.
- Especially good sources of this widely distributed vitamin include egg yolk, kidney, liver, tomatoes, and yeast.

Biotin

- There is no known toxicity to biotin. The estimated safe and adequate daily intake for adults is 100 to 200 micrograms.

Folic Acid

- Folic acid (pteroylglutamic acid, folacin, or vitamin B_9) occurs abundantly in green leafy vegetables, fruits (e.g., apples and oranges), dried beans, avocados, sunflower seeds, and wheat germ.

Folic Acid

- Derivatives of this vitamin are directly involved in the **synthesis of nucleic acids**; for this reason cells in the body that are subject to rapid synthesis and destruction are especially sensitive to folic acid deprivation.

Folic Acid

- For example, the retarded synthesis of blood cells in folic acid deficiency results in several forms of anemia, while failure to replace rapidly destroyed cells in the intestinal wall results in a disease called sprue.

Folic Acid

- Inadequate amounts of folic acid in the diet of pregnant women have been strongly associated with neural tube defects (i.e., **spina bifida** and anencephaly) in newborns; fortification of flours, cornmeal, rice, and pasta (in a manner similar to the fortification of milk with vitamin D) has been required in the United States since 1998.

Folic Acid

- Adequate folic acid also reduces the risk of premature birth.
- A U.S. study published in 1998 involving 80,000 women showed significant reduction of heart disease among those whose diets included adequate amounts of folate and vitamin B_6.

Folic Acid

- Several chemical antagonists to the action of folic acid have been developed in the hope that they might inhibit the growth of rapidly dividing cancer cells; one such compound, methotrexate, is used to treat **leukemia** in children.

Folic Acid

- The recommended daily dietary allowance for adults is 400 micrograms.
- **Para-aminobenzoic acid** (**PABA**), which is incorporated into the folic acid molecule, is sometimes listed separately as a B vitamin, although there is no evidence that it is essential to the diet of humans.

Vitamin B_{12}

- The molecular structure of vitamin B_{12} (cobalamin), the most complex of all known vitamins.
- Vitamin B_{12} and closely related cobalamins are necessary for folic acid to fulfill its role; both are **involved in the synthesis of proteins**.

Vitamin B_{12}

- Inadequate absorption of B_{12} causes pernicious anemia, nervous system degeneration, and amenorrhea.
- The only site of cobalamin synthesis in nature appears to be in microorganisms; neither animals nor higher plants are capable of making these vitamin B_{12} derivatives.

Vitamin B_{12}

- Nevertheless, such animal tissues as the liver, kidney, and heart of ruminants contain relatively large quantities of vitamin B_{12};
- The vitamin stored in these organs was originally produced by the bacteria in the ruminant gut.

Vitamin B_{12}

- Bivalves (clams or oysters), which siphon microorganisms from the sea, are also good sources.
- Plants, on the other hand, are poor sources of vitamin B_{12}.
- The recommended daily dietary allowance for adults is 3 micrograms.

Vitamin C

- Vitamin C, or **ascorbic acid**, a water-soluble vitamin, was first isolated (from adrenal cortex, oranges, cabbage, and lemon juice) in the years 1928-33.
- Szent-Gyorgyi found the Hungarian red pepper to be an exceptionally rich source; citrus fruits and tomatoes are also excellent sources.

Vitamin C

- Other good sources include berries, fresh green and yellow vegetables, and white potatoes and sweet potatoes.
- The vitamin is readily oxidized and therefore is easily destroyed in cooking and during storage.
- All animals except **humans**, other primates, **guinea pigs**, and **one bat and bird species** are able to synthesize ascorbic acid.

Vitamin C

- Ascorbic acid is necessary for the synthesis of the body's cementing substances: bone matrix, **collagen**, dentin, and cartilage.
- It is an **antioxidant** and is necessary to several metabolic processes.
- Deficiency of vitamin C results in **scurvy**, the symptoms of which are largely related to inadequate collagen synthesis and defective formation of intercellular materials.

Vitamin C

- Ascorbic acid is metabolized slowly in humans, and symptoms of scurvy are usually not seen for three or four months in the absence of any dietary vitamin C.
- The use of megadoses of ascorbic acid to prevent common colds, stress, mental illness, cancer, and heart disease is a continuing subject of research.

Vitamin C

- A study conducted in Great Britain in 1998 found that 500 mg of vitamin C daily had pro-oxidant as well as antioxidant effects and could damage DNA, the genetic material.
- The recommended daily allowance for adults is 60 mg.

Vitamin D

- Vitamin D is a name given to two fat-soluble compounds; calciferol (vitamin D_2) and cholecalciferol (vitamin D_3).
- They are now known to be hormones, but continue to be grouped with vitamins because of historical misclassification. Vitamin D_3 plays an essential role in the metabolism of calcium and phosphorus in the body and prevents **rickets** in children.

Vitamin D

- A plentiful supply of 7-dehydrocholesterol, the precursor of vitamin D_3, exists in human skin and needs only to be activated by a moderate amount of ultraviolet light (less than a half hour of sunlight) to become fully potent.

Vitamin D

- **Rickets** is usually caused by a lack of exposure to sunlight rather than a dietary deficiency, although dietary deficiencies can result from malabsorption in the small intestine caused by conditions such as sprue or colitis.

Vitamin D

- Rickets can be prevented and its course halted by the intake of vitamin D_2 (found in irradiated yeast and used in some commercial preparations of the vitamin) or vitamin D_3 (found in fish liver oils and in fortified milk).
- Symptoms of vitamin D deficiency in children include bowlegs, knock knees, and more severe (often crippling) deformations of the bones.

Vitamin D

- In adults deficiency results in osteomalacia, characterized by a softening of the bones.
- Excessive vitamin D consumption can result in toxicity.
- Symptoms include nausea, loss of appetite, kidney damage, and deposits of insoluble calcium salts in certain tissues.

Vitamin D

- The recommended daily dietary allowance for cholecalciferol is 5 to 10 micrograms (200 to 400 IU) depending upon age and the availability of sunlight. Fortified cow's milk supplies 400 IU per quart (422 IU per liter).

Vitamin E

- Like Vitamins B and C, Vitamin E is stored in the body for a relatively short time.
- It is believed to be an important vasodilator and anticoagulant.
- Selenium increases E’s potency.

Vitamin E

- Vitamin E (tocopherol) occurs in at least seven molecular forms, designated alpha-, beta-, gamma-, delta-, epsilon-, zeta-, and eta-tocopherol; all exist as light yellow, viscous oils.

Vitamin E

- The best source is vegetable oils.
- Other sources include green leafy vegetables, wheat germ, and eggs.
- Tocopherol is necessary for the **maintenance of cell membranes**.
- It is essential to normal reproduction in some animals, but there is no evidence that it plays a role in human reproduction.

Vitamin E

- It is a potent **antioxidant**; numerous studies have pointed to a protective effect against arterial plaque buildup and cancer.
- It is helpful in the relief of intermittent claudication (calf pain) and in preventing problems peculiar to premature infants.
- In large doses, it has an anticoagulant effect.

Vitamin E

- The recommended daily dietary allowance for adults is 10 mg (tocopherol equivalents) for men and 8 mg for women, but nutritionists and physicians sometimes recommend higher doses for disease prevention.

Vitamin K

- Vitamin K consists of substances that are essential for the clotting of blood.
- Two types of K vitamins have been isolated: K_1, an oil purified from alfalfa concentrates, and K_2, synthesized by the normal intestinal bacteria.

Vitamin K

- Both can be derived from the synthetic compound menadione (sometimes called vitamin K_3), a yellow crystalline solid that is as potent in its ability to promote blood clotting as the natural vitamins.
- The best sources are leafy green vegetables, such as cabbage and spinach, and intestinal bacteria (which produce most of the body's supply of vitamin K).

Vitamin K

- Vitamin K is required for the synthesis in the liver of several blood clotting factors, including prothrombin. Coumarin derivatives, used in medicine to prevent blood coagulation in certain cases, act by antagonizing the action of vitamin K.
- In the deficiency state an abnormal length of time is needed for the blood to clot, and there may be hemorrhaging in various tissues.

Vitamin K

- Deficiency occurs in hemorrhagic disease of the newborn infant, in liver damage, and in cases where the vitamin is not absorbed properly by the intestine.
- It can also occur in coumarin therapy or when normal intestinal bacteria are destroyed by extended antibiotic therapy.

Vitamin K

- Vitamin K does not treat hemophilia.
- Deficiency is rarely of dietary origin. The estimated safe and adequate intake for adults is 70 to 140 micrograms.

TABLE 5–1. UNITED STATES RECOMMENDED DAILY ALLOWANCES (U.S. RDA) FOR PROTEIN, VITAMINS, AND MINERALS, AND THE RECOMMENDED DIETARY INTAKE OF PROTEIN FOR ADULTS EXPRESSED AS GRAMS PER KILOGRAM OF BODY MASS (G/KG)

U.S. RECOMMENDED DAILY ALLOWANCES (U.S. RDA)

Vitamins and Minerals	Unit of Measurement	Adults and Children 4 or More Years of Age	Infants	Children Under 4 Years of Age	Pregnant or Lactating Women
Vitamin A	International units	5000	1500	2500	8000
Vitamin D	International units	400	400	400	400
Vitamin E	International units	30	5.0	10	30
Vitamin C	Milligrams	60	35	40	60
Folic acid	Milligrams	0.4	0.1	0.2	0.8
Thiamin	Milligrams	1.5	0.5	0.7	1.7
Riboflavin	Milligrams	1.7	0.6	0.8	2.0
Niacin	Milligrams	20	8.0	9.0	20
Vitamin B_4	Milligrams	2.0	0.4	0.7	2.5
Vitamin B_{12}	Micrograms	6.0	2.0	3.0	8.0
Biotin	Milligrams	0.3	0.05	0.15	0.3
Pantothenic acid	Milligrams	10	3.0	5.0	10
Calcium	Grams	1.0	0.6	0.8	1.3
Phosphorus	Grams	1.0	0.5	0.8	1.3
Iodine	Micrograms	150	45	70	150
Iron	Milligrams	18	15	10	18
Magnesium	Milligrams	400	70	200	450
Copper	Milligrams	2.0	0.6	1.0	2.0
Zinc	Milligrams	15	5.0	8.0	15

RECOMMENDED DIETARY ALLOWANCES OF PROTEIN FOR ADOLESCENT AND ADULT MEN AND WOMEN				
	Men		Women	
Recommended Amount	Adolescent	Adult	Adolescent	Adult
Grams of protein per kilogram of body mass	0.9	0.8	0.9	0.8
Grams per day based on average weight*	59	56	50	44

* For adolescents, average weight is approximately 65.8 kg (145 lb) for males and 55.7 kg (123 lb) for females. For adult men, average weight is 70 kg (154 lb). For adult women, average weight is 55 kg (120 lb).

TABLE 6–2. RECOMMENDED DIETARY INTAKE, FOOD SOURCES, MAJOR BODILY FUNCTIONS, AND SYMPTOMS OF DEFICIENCY OR EXCESS OF THE FAT-SOLUBLE VITAMINS FOR HEALTHY ADULTS (AGE 19–50)*

VITAMIN	RDA FOR MALES AND FEMALES† (MG)	DIETARY SOURCES	MAJOR BODY FUNCTIONS	DEFICIENCY	EXCESS
Vitamin A (retinol)	1.0 0.8	Provitamin A (beta-carotene) widely distributed in green vegetables. Retinol present in milk, butter, cheese, fortified margarine	Constituent of rhodopsin (visual pigment). Maintenance of epithelial tissues. Role in mucopolysaccharide synthesis	Xerophthalmia (keratinization of ocular tissue), night blindness, permanent blindness	Headache, vomiting, peeling of skin, anorexia, swelling of long bones
Vitamin D	0.01‡ 0.01	Cod-liver oil, eggs, dairy products, fortified milk, and margarine	Promotes growth and mineralization of bones. Increases absorption of calcium	Rickets (bone deformities) in children. Osteomalacia in adults	Vomiting, diarrhea, loss of weight, kidney damage
Vitamin E (tocopherol)	10 8	Seeds, green leafy vegetables, margarines, shortenings	Functions as an antioxidant to prevent cell membrane damage	Possibly anemia	Relatively nontoxic
Vitamin K (phylloquinone)	0.08 0.06	Green leafy vegetables. Small amount in cereals, fruits, and meats	Important in blood clotting (involved in formation of active prothrombin)	Conditioned deficiencies associated with severe bleeding; internal hemorrhages	Relatively nontoxic. Synthetic forms at high doses may cause jaundice

* Recommended Dietary Allowances. Revised 1989. Food and Nutrition Board, National Academy of Sciences–National Research Council, Washington, D.C.
† First values are for males.
‡ 0.005 mg for adults 25 and older.

TABLE 6–3. RECOMMENDED DIETARY INTAKE, FOOD SOURCES, MAJOR BODILY FUNCTIONS, AND SYMPTOMS OF DEFICIENCY OR EXCESS OF THE WATER-SOLUBLE VITAMINS FOR HEALTHY ADULTS (AGE 19–50)*

VITAMIN	RDA FOR MALES AND FEMALES† (MG)	DIETARY SOURCES	MAJOR BODY FUNCTIONS	DEFICIENCY	EXCESS
Vitamin B_1 (thiamin)	1.5 1.1	Pork, organ meats, whole grains, legumes	Coenzyme (thiamine pyrophosphate) in reactions involving the removal of carbon dioxide	Beriberi (peripheral nerve changes, edema, heart failure)	None reported
Vitamin B_2 (riboflavin)	1.7 1.3	Widely distributed in foods	Constituent of two flavin nucleotide coenzymes involved in energy metabolism (FAD and FMN)	Reddened lips, cracks at mouth corner (cheilosis), eye lesions	None reported
Niacin	19 15	Liver, lean meats, grains, legumes (can be formed from tryptophan)	Constituent of two coenzymes in oxidation-reduction reactions (NAD and NADP)	Pellagra (skin and gastrointestinal lesions, nervous, mental disorders)	Flushing, burning and tingling around neck, face, and hands
Vitamin B_6 (pyridoxine)	2.0 1.6	Meats, vegetables, whole-grain cereals	Coenzyme (pyridoxal phosphate) involved in amino acid and glycogen metabolism	Irritability, convulsions, muscular twitching, dermatitis, kidney stones	None reported
Pantothenic acid	4–7§ 4–7	Widely distributed in foods	Constituent of coenzyme A, which plays a central role in energy metabolism	Fatigue, sleep disturbances, impaired coordination, nausea	None reported

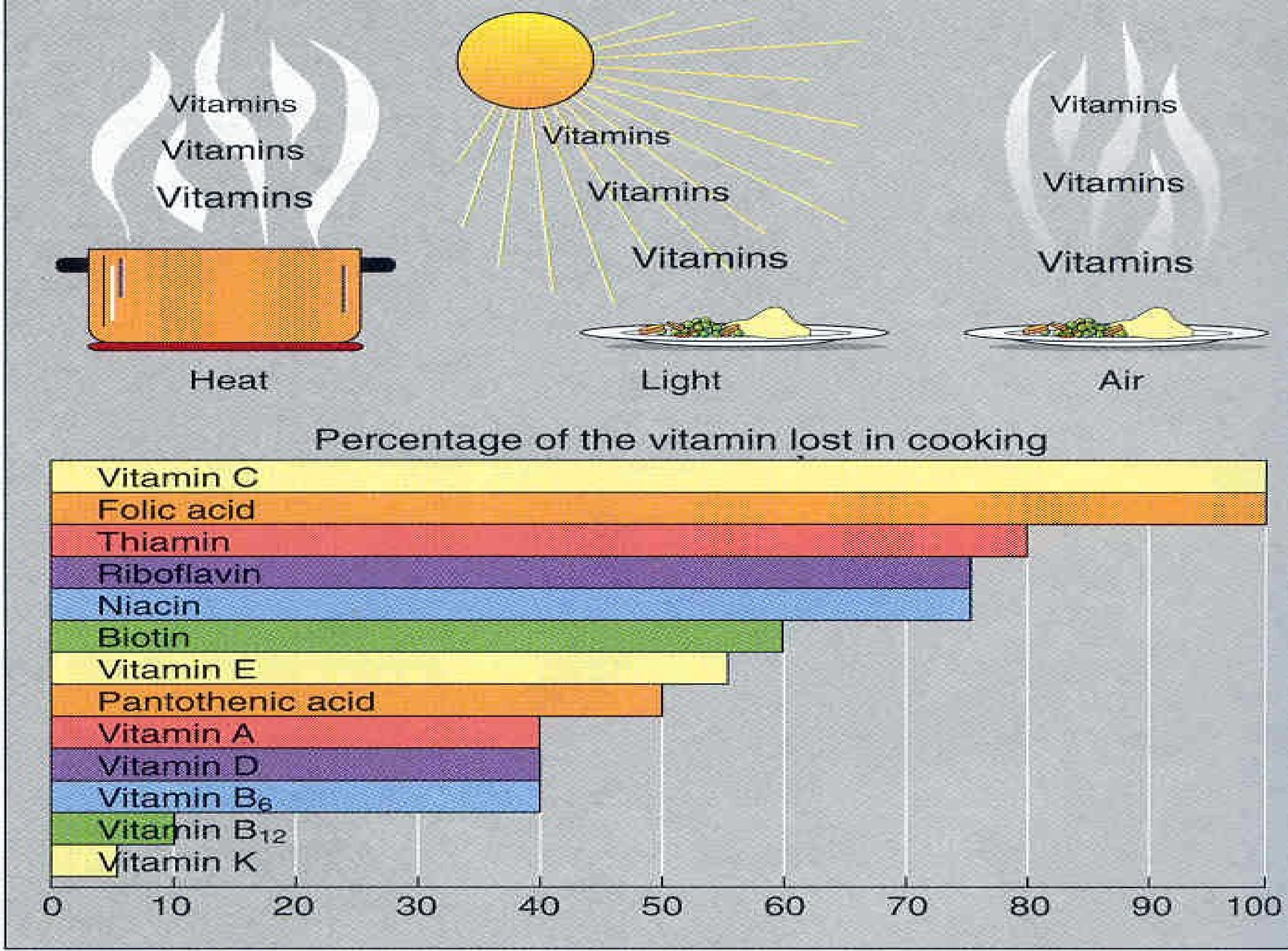
			lism		
Folacin	0.2 0.2	Legumes, green vegetables, whole-wheat products	Coenzyme (reduced form) involved in transfer of single-carbon units in nucleic acid and amino acid metabolism	Anemia, gastrointestinal disturbances, diarrhea, red tongue	None reported
Vitamin B_{12}	0.002 0.002	Muscle meats, eggs, dairy products, (absent in plant foods)	Coenzyme involved in transfer of single-carbon units in nucleic acid metabolism	Pernicious anemia, neurologic disorders	None reported
Biotin	0.03–0.10§	Legumes, vegetables, meats	Coenzymes required for fat synthesis, amino acid metabolism, and glycogen (animal starch) formation	Fatigue, depression, nausea, dermatitis, muscular pains	None reported
Vitamin C (Ascorbic acid)	60‡ 60	Citrus fruits, tomatoes, green peppers, salad greens	Maintains intercellular matrix of cartilage, bone, and dentine. Important in collagen synthesis.	Scurvy (degeneration of skin, teeth, blood vessels, epithelial hemorrhages)	Relatively nontoxic. Possibility of kidney stones

* Recommended Dietary Allowances. Revised 1989. Food and Nutrition Board, National Academy of Sciences–National Research Council, Washington, D.C.

† First values are for males.

‡ 100 for adults who smoke.

§ Because there is less information on which to base allowances, these figures are given in the form of ranges.


Vitamins
Vitamins
Vitamins
Heat
Vitamins
Vitamins
Vitamins
Light
Vitamins
Vitamins
Vitamins
Air
Percentage of the vitamin lost in cooking
Vitamin C
Folic acid
Thiamin
Riboflavin
Niacin
Biotin
Vitamin E
Pantothenic acid
Vitamin A
Vitamin D
Vitamin B_6
Vitamin B_{12}
Vitamin K
0
10
20
30
40
50
60
70
80
90
100

Quantitatively almost inconsequential. Annual adult requirement for 11 vitamins

VITAMIN RDA	ANNUAL ADULT REQUIREMENT	
	Males	Females
Vitamin A, μg RE*	365,000	292,000
Vitamin D, μg	3,650	1,825
Vitamin E, mg α-TE†	3,650	2,920
Vitamin K, μg	29,200	23,725
Vitamin C, mg	21,900	21,900
Thiamine, mg	548	402
Riboflavin, mg	621	475
Folic acid, mg NE‡	6,935	5,475
Vitamin B_6, mg	730	584
Folate, μg	73,000	65,700
Vitamin B_{12}, μg	730	730

* Retinol Equivalents.
† α-Tocopherol Equivalents.
‡ Niacin Equivalents.

ANTIOXIDANTS

Antioxidant

- **Antioxidant** are substances that prevents or slows the breakdown of another substance by **oxygen**.
- Synthetic and natural antioxidants are used to slow the deterioration of foods and such antioxidants as vitamin C (ascorbic acid), butylated hydroxytoluene (BHT), and butylated hydroxyanisole (BHA) are added to foods to prevent them from becoming rancid or from discoloring.

Antioxidant

- In the body, nutrients such as beta-carotene (a vitamin A precursor), vitamin C, vitamin E, and selenium have been found to act as antioxidants.
- They act by scavenging **free radicals,** molecules with one or more unpaired electrons, which rapidly react with other molecules, starting chain reactions in a process called oxidation.

Antioxidant

- Free radicals are a normal product of metabolism; the body produces its own antioxidants (e.g., the enzyme superoxide dismutase) to keep them in balance.
- However, stress, aging, and environmental sources such as polluted air and cigarette smoke can add to the number of free radicals in the body, creating an imbalance.

Antioxidant

- The highly reactive free radicals can damage healthy DNA and have been linked to changes that accompany aging (such as age-related macular degeneration, a leading cause of blindness in older people) and with disease processes that lead to cancer, heart disease, and stroke.

Antioxidant

- Studies have suggested that the antioxidants that occur naturally in fresh fruits and vegetables have a protective effect.
- For example, vitamin E and beta-carotene appear to protect cell membranes; vitamin C removes free radicals from inside the cell.

Antioxidant

- There is still some question as to whether antioxidants in the form of dietary supplements counteract the effects of increased numbers of free radicals in the body.
- Some scientists believe that regular consumption of such supplements interferes with the body's own production of antioxidants.

Free Radical

- **Free radical,** in chemistry, a molecule or atom that contains an unpaired electron but is neither positively nor negatively charged.
- Free radicals are usually highly reactive and unstable.

NUCLEIC ACIDS

DNA - Deoxyribonucleic Acid

RNA - Ribonucleic Acid

Nucleic Acids

- *Nucleic* acids are huge organic molecules that contain carbon, hydrogen, oxygen, nitrogen, and phosphorus.
  - Deoxyribonucleic Acid (**DNA**) and
  - Ribonucleic Acid (**RNA**)

Nucleic Acids

- *Deoxyribonucleic acid* (**DNA**) forms the genetic code inside each cell and thereby regulates most of the activities that take place in our cells throughout a lifetime.
- The **Nucleotide** is the function unit of both DNA and RNA.

Nucleotide

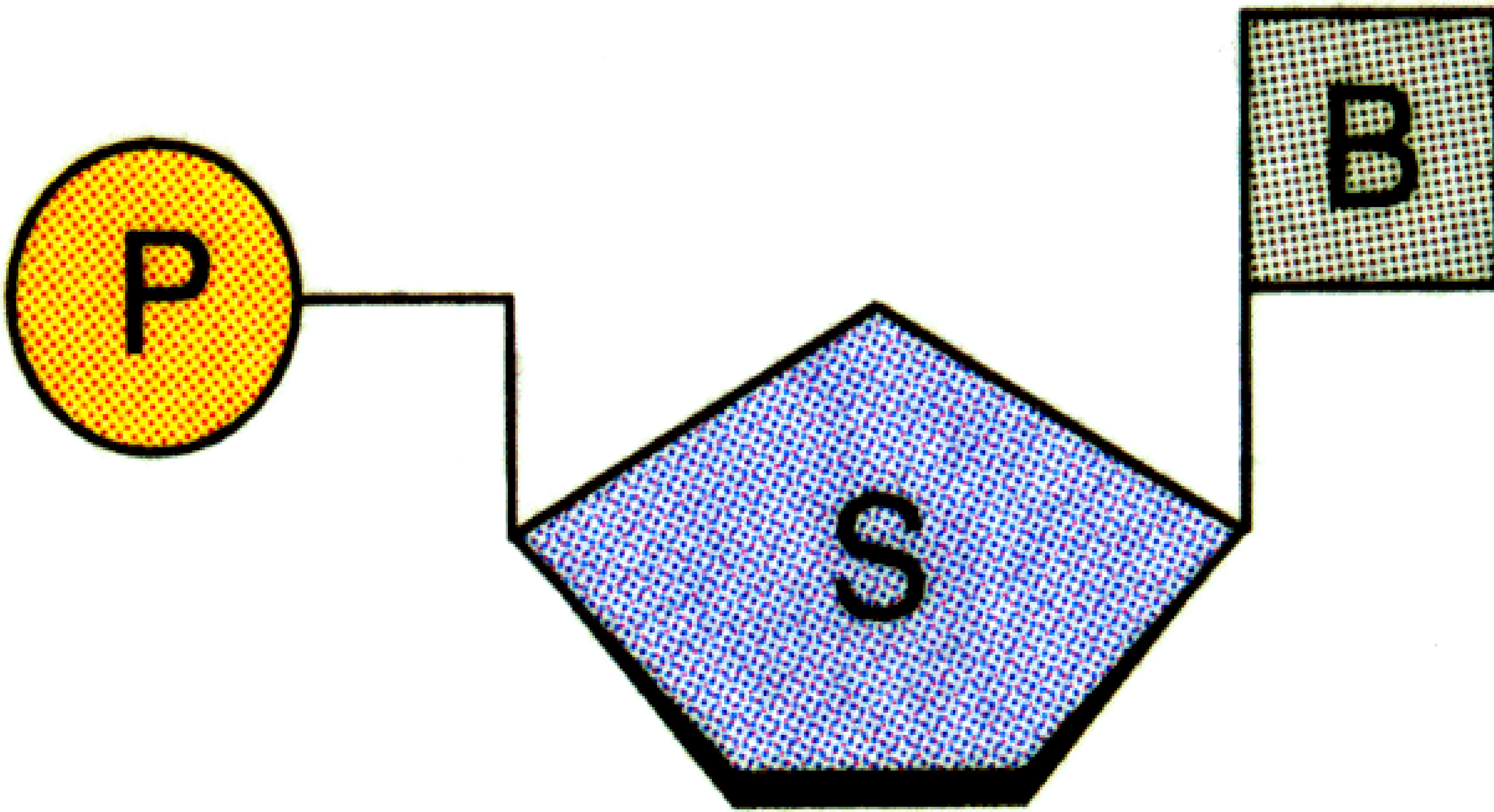
- The Nucleotide consists of three parts:

1. A **phosphate** group (PO_4^{3-}) ,
2. A 5-carbon pentose sugar (Deoxyribose in DNA & Ribose in RNA), and
3. One of 4 nitrogenous bases
   - Adenine (A)
   - Thymine (T) –Uracil (U) replaces it in RNA
   - Cytosine (C)
   - Guanine (G)

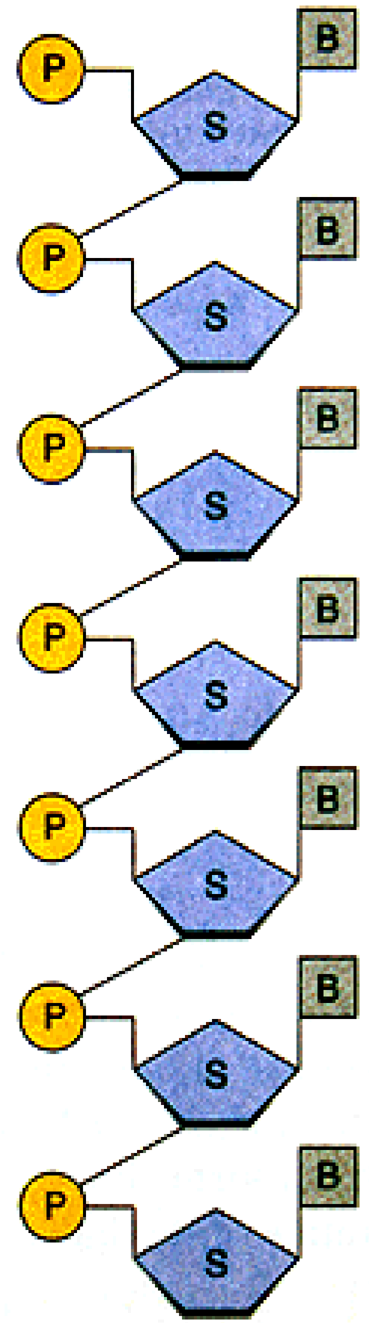
Nucleotide

- The phosphate groups (PO_4^{3-}) and the pentose sugars form the **backbone** of both DNA and RNA.

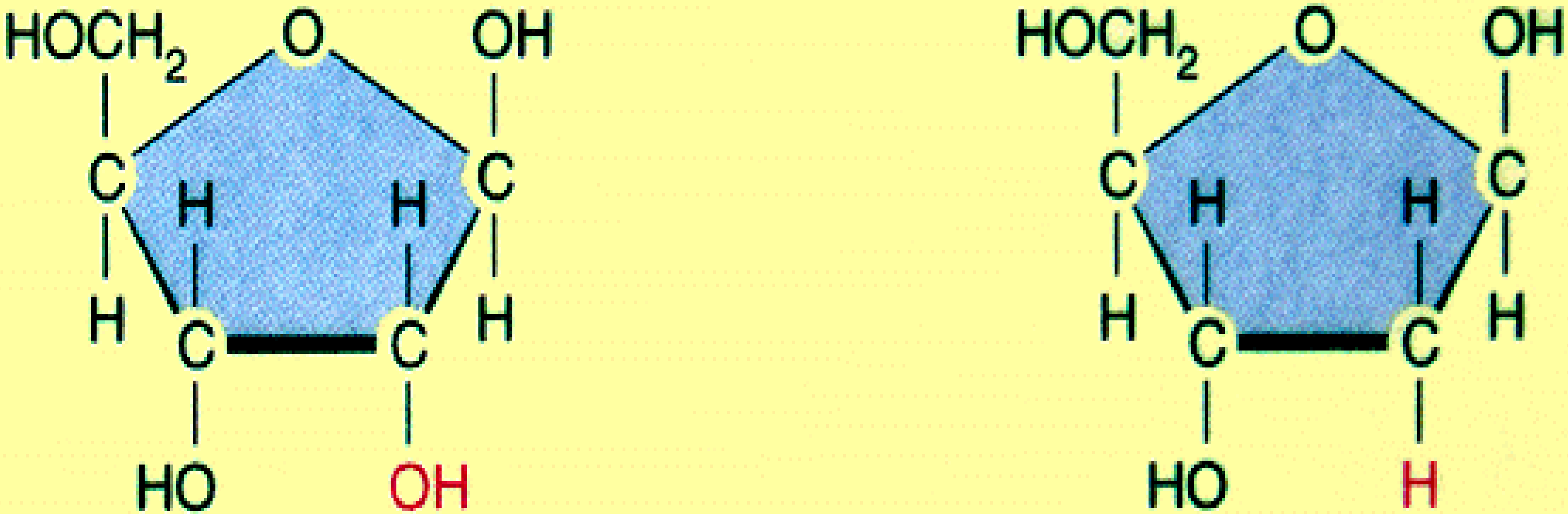
Nucleotide.



Polynucleotide Chain.

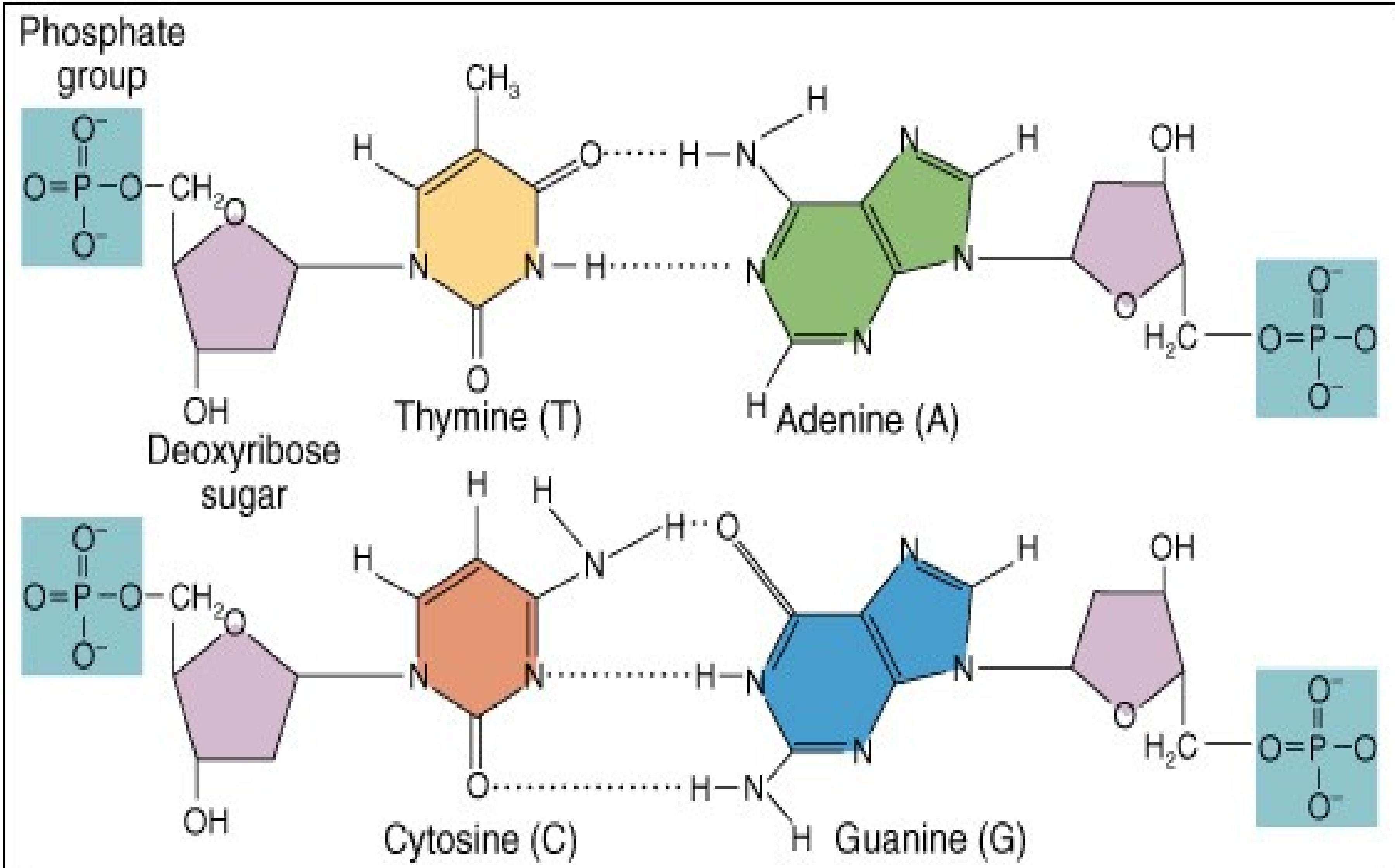


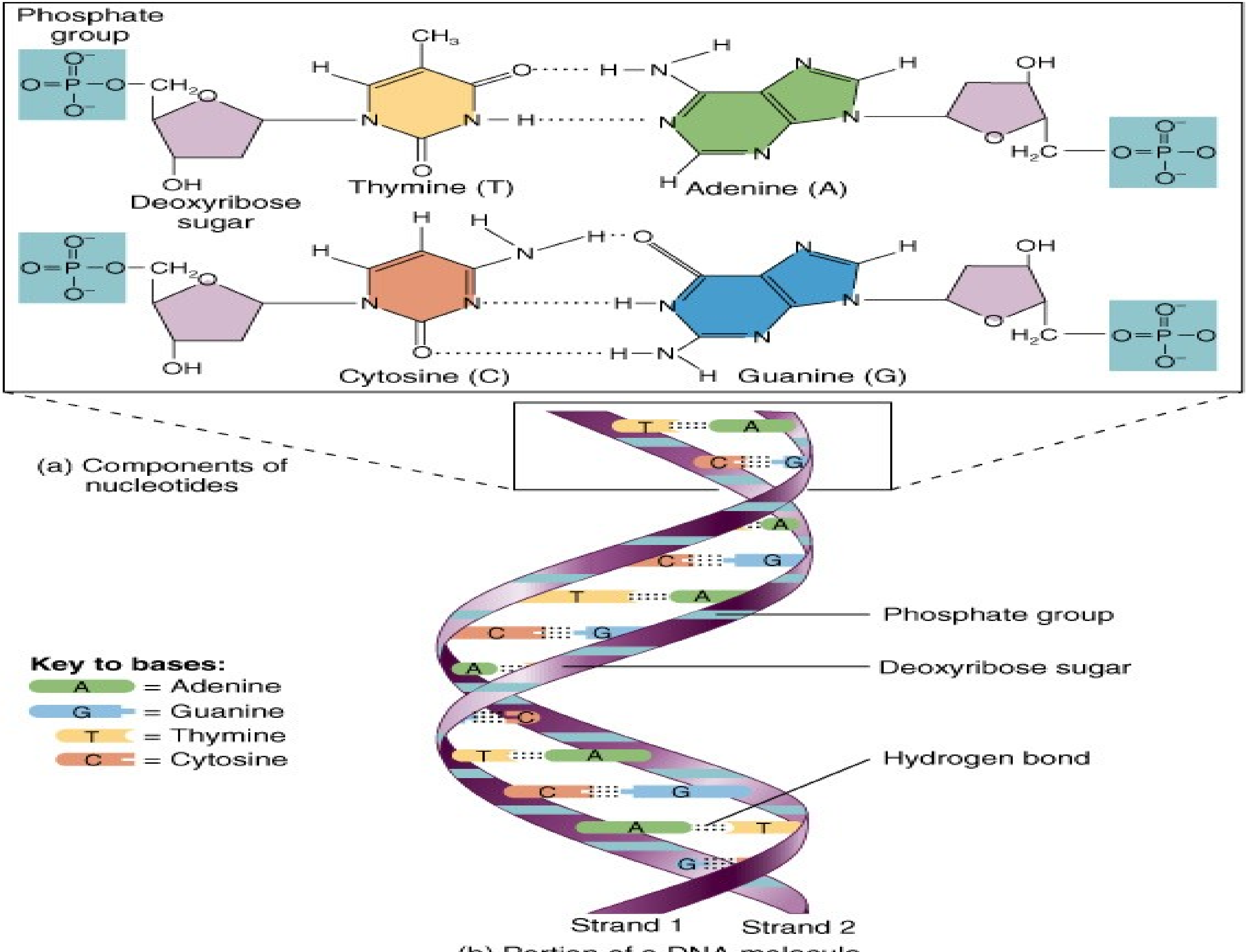
Ribose and Deoxyribose.



Ribose

Deoxyribose


Phosphate group
Deoxyribose sugar
Thymine (T)
Adenine (A)
Cytosine (C)
Guanine (G)


Phosphate group
Deoxyribose sugar
Thymine (T)
Adenine (A)
Cytosine (C)
Guanine (G)
(a) Components of nucleotides
Key to bases:
A = Adenine
G = Guanine
T = Thymine
C = Cytosine
Phosphate group
Deoxyribose sugar
Hydrogen bond
Strand 1
Strand 2
(b) Portion of a DNA molecule

Nucleic Acids

- *Ribonucleic acid* (**RNA**) relays instructions from the genes in the cell's nucleus to guide each cell's assembly of amino acids into proteins by the ribosomes.
- The basic units of nucleic acids are **nucleotides**, composed of a nitrogenous base, a pentose, sugar, and a phosphate group (Fig. 2.25).

RNA

- RNA, or ribonucleic acid, is chemically similar to DNA, except it is single-stranded, not double-stranded;
- It contains the base uracil (U) instead of thymine (T); it can migrate out of the nucleus.
- The sequences of most RNA molecules are translated to make proteins.

ADENOSINE TRIPHOSPHATE

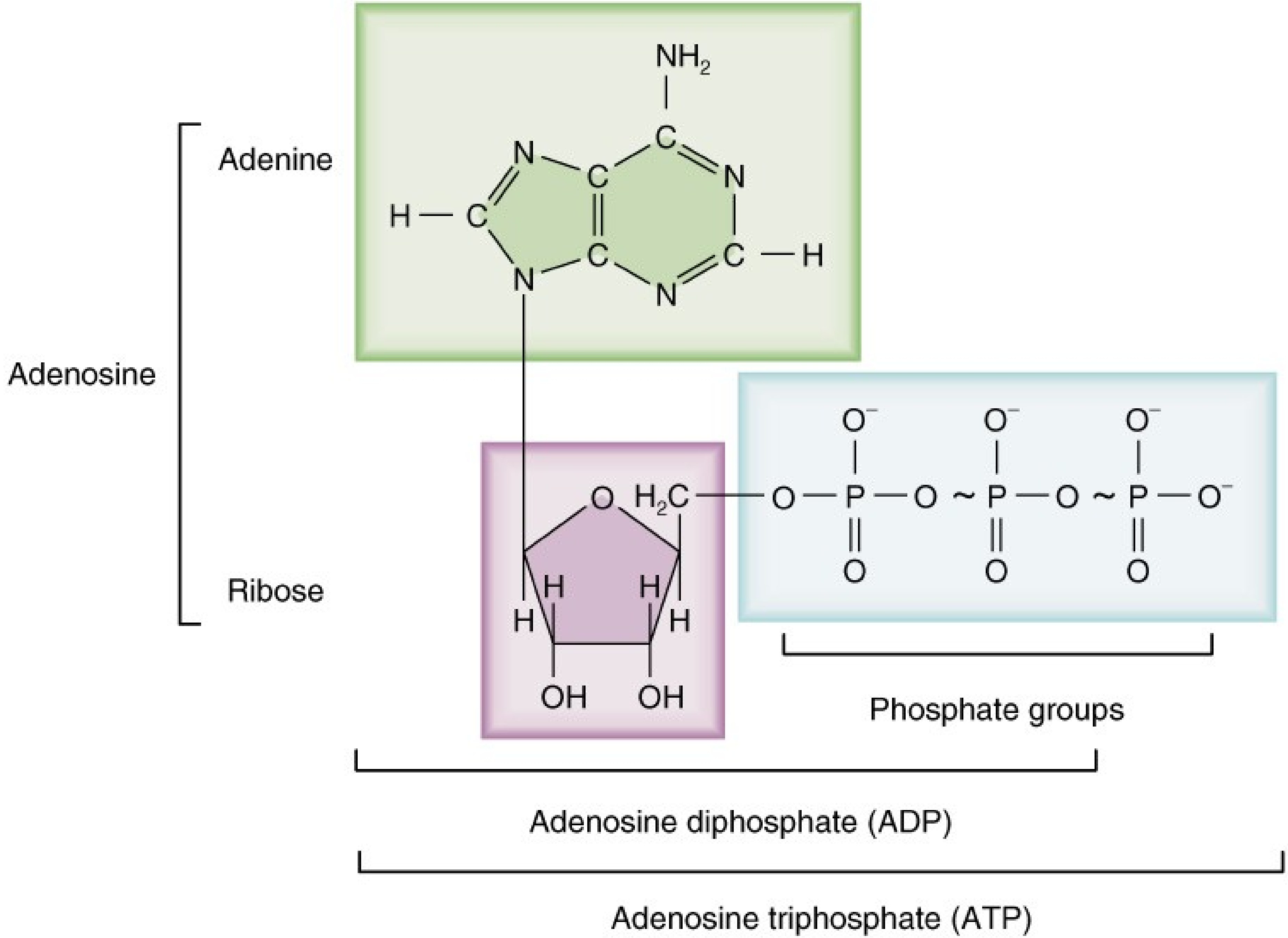
ATP

Adenosine Triphosphate

- Adenosine triphosphate (**ATP**) is the principal energy-storing molecule in the body.
- Among the cellular activities for which ATP provides energy are muscular contractions, chromosome movement during cell division, cytoplasmic movement within cells, membrane transport processes, and synthesis reactions.

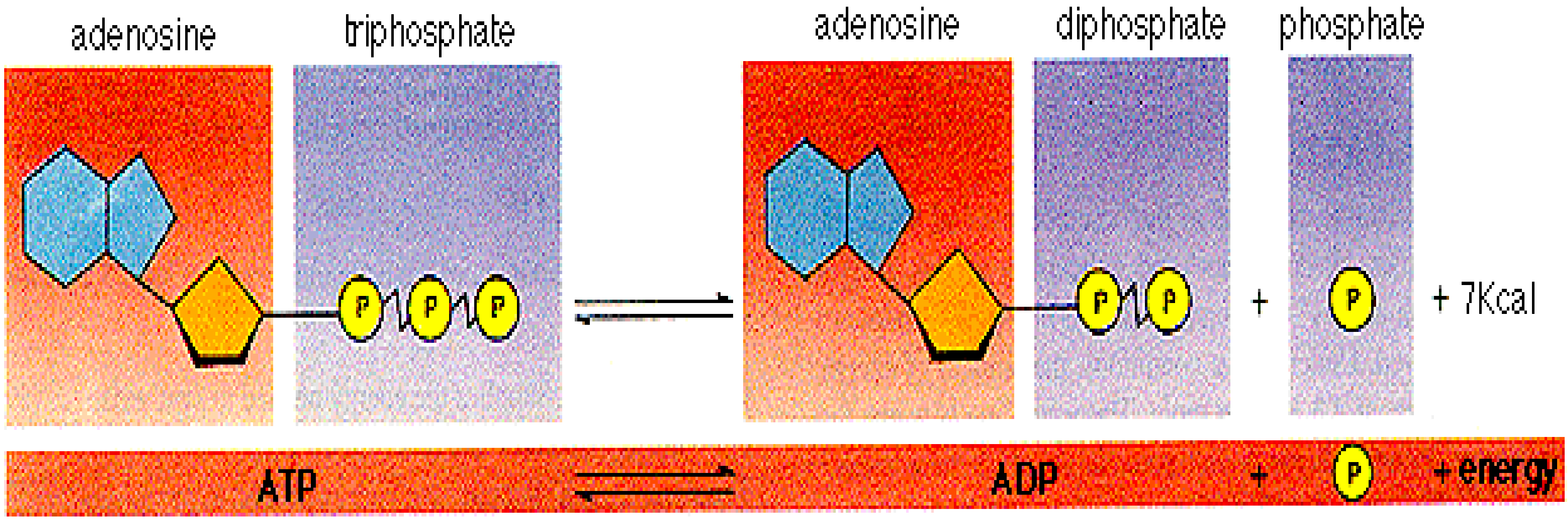
Adenosine Triphosphate

- ATP consists of <u>three phosphate</u> groups attached to an adenosine unit composed of adenine and the five-carbon sugar ribose
- When energy is liberated from ATP, it is decomposed to adenosine diphosphate (ADP) and phosphorus (**P**).



Adenosine
Adenine
Ribose
Phosphate groups
Adenosine diphosphate (ADP)
Adenosine triphosphate (ATP)

Figure 2
ATP reaction.



Adenosine Triphosphate

- ATP is manufactured from ADP and P using the energy supplied by various decomposition reactions, particularly that of **glucose**.

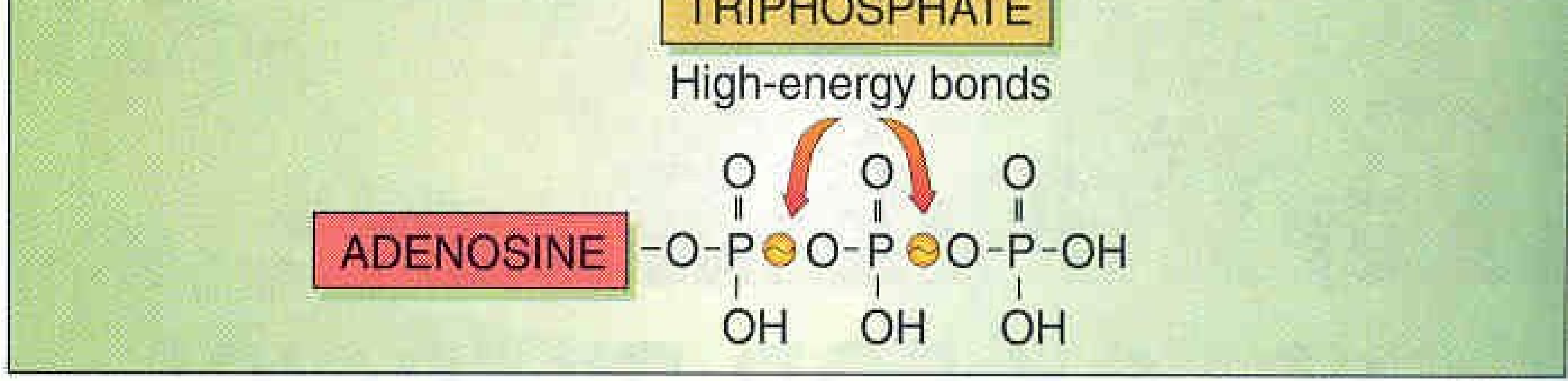


FIG. 11–1. Simplified structure of ATP, the energy currency of the cell. The symbol (~) represents the high-energy bonds.

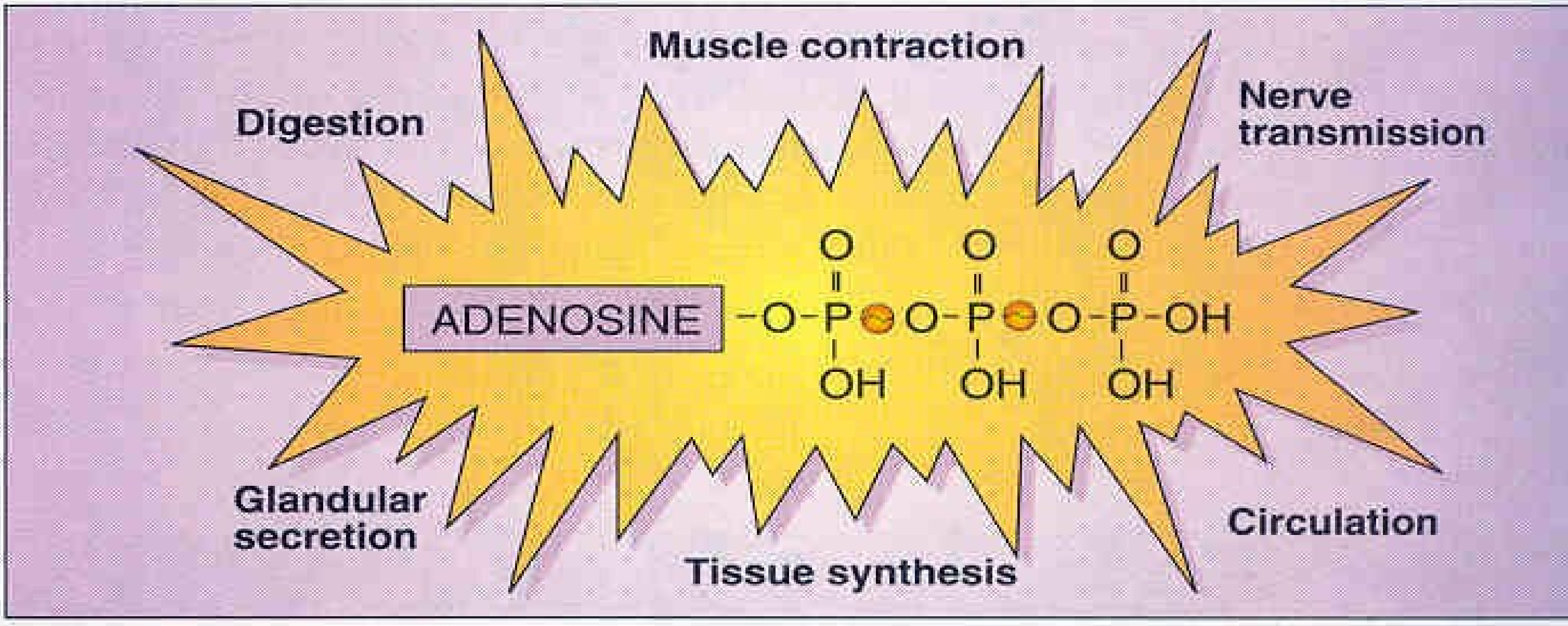


FIG. 11–2. ATP is the energy currency for all forms of biologic work.

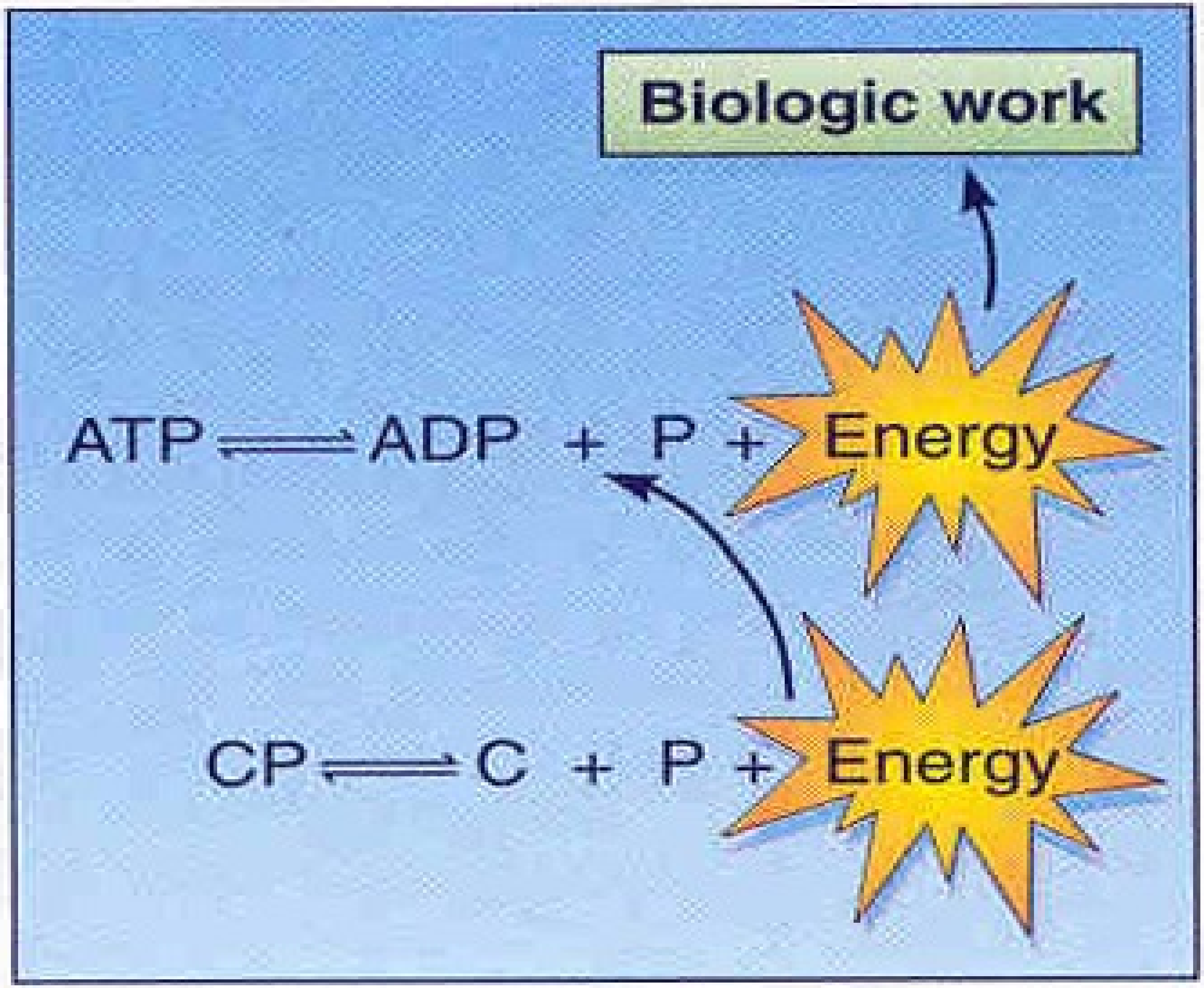
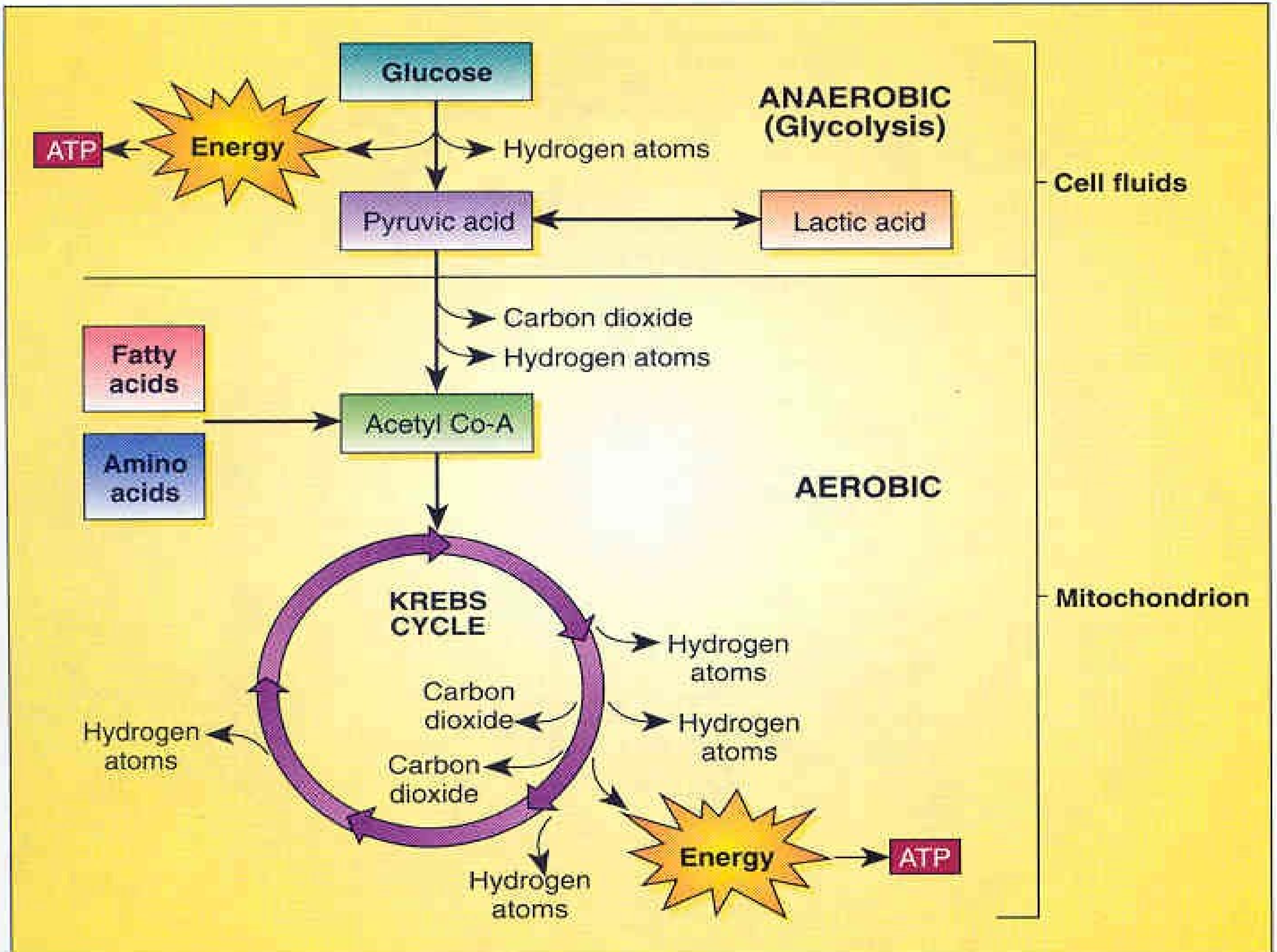
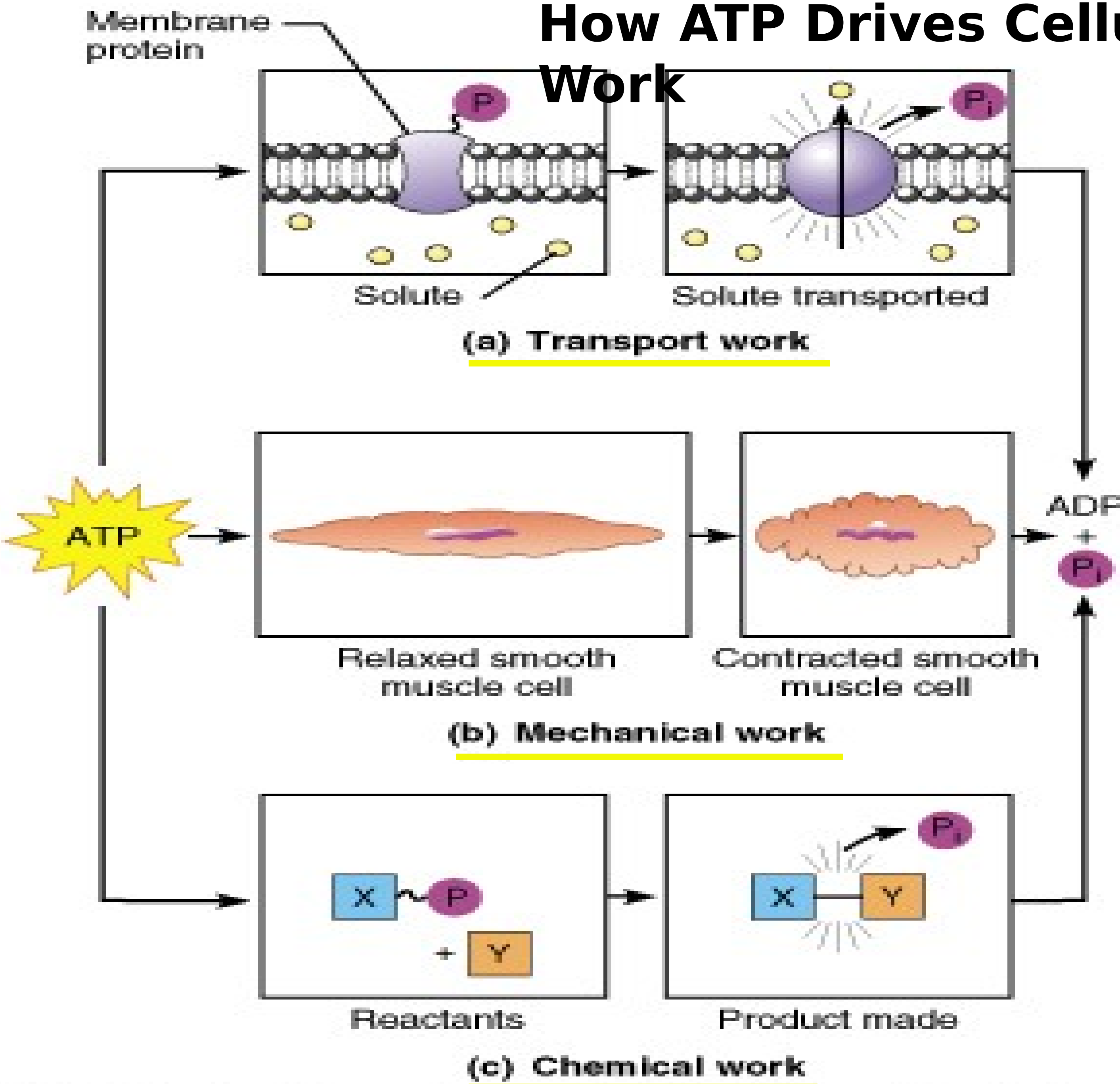


FIG. 11–3. ATP and CP are anaerobic sources of phosphate-bond energy. The energy from the breakdown of CP is used to rebond ADP and P to form ATP.


Glucose
ANAEROBIC
(Glycolysis)
ATP
Energy
Hydrogen atoms
Cell fluids
Pyruvic acid
Lactic acid
Carbon dioxide
Hydrogen atoms
Fatty acids
Acetyl Co-A
Amino acids
AEROBIC
KREBS CYCLE
Mitochondrion
Hydrogen atoms
Carbon dioxide
Hydrogen atoms
Hydrogen atoms
Carbon dioxide
Hydrogen atoms
Energy
ATP

How ATP Drives Cellular Work



QUESTIONS